What Organized the Nervous System Before It Could Organize Anything Else?

Cognition is Organized at the Sensory Surface Not in the Brain

Caught In A Line
The explanatory model of all motoric movement actions

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Abstract

Cognitive neuroscience has traditionally assumed that the primary organization of perception and cognition resides within the brain. Although contemporary frameworks—including representational theories, predictive coding, internal models, dynamical systems theory, neural manifolds, and large-scale population dynamics—propose fundamentally different computational mechanisms, they continue to share this central assumption. This assumption, however, raises a fundamental evolutionary question: if the brain constitutes the primary organization of perception and cognition, what organized the nervous system itself before it could organize anything else?

Long before nervous systems evolved, the physical world already consisted of continuously organized dynamics. Light, sound, mechanical forces, chemical gradients, temperature, gravity, and every other physical process unfolded as uninterrupted causal sequences in which each state necessarily emerged from the preceding state while constraining the next. Consequently, the external surfaces of evolving organisms were continuously bombarded by adjacent temporal units of externally specified physical dynamics. Organisms therefore evolved within an already organized world rather than constructing that organization through neural computation. Because this externally specified organization preceded the evolution of nervous systems, the primary organization of cognition cannot originally have arisen within the brain itself.

Building upon this evolutionary asymmetry, the Gramophone Model (GM) proposes that the primary organization of cognition resides at the sensory surface: the functional interface where externally specified physical dynamics continuously encounter the organism. The brain is consequently reinterpreted not as the origin of cognitive organization, but as an evolutionarily developed biological stabilization system that preserves, coordinates, and optimizes an organization that is already specified at the sensory surface. Neural architecture is therefore understood as the accumulated consequence of previous organism–environment interactions rather than as the source of perception and cognition.

This perspective provides a unified reinterpretation of recurrent cortical connectivity, extensive feedback pathways, traveling waves, neural manifolds, representational drift, and large-scale brain dynamics as complementary mechanisms of biological stabilization rather than as the primary generators of cognition. Rather than asking how the brain organizes cognition, the more fundamental evolutionary question becomes how an already organized external world shaped the evolution of sensory systems and, ultimately, the brain itself.

Keywords: *Sensory surface; Cognitive organization; Evolution of cognition; Evolution of the nervous system; Organism–environment coupling; Ecological cognition; External dynamics; Neural stabilization; Brain evolution; Sensory transduction; Large-scale brain dynamics; Neural manifolds; Traveling waves; Representational drift; Cortical feedback; Predictive coding; Internal models; Dynamical systems; Ecological psychology; Gramophone Model.*

Introduction

The Evolutionary Paradox of Brain-Centered Cognition

Where is the primary organization of cognition located? Although this question lies at the foundation of cognitive neuroscience, it is rarely addressed explicitly. Virtually all major theoretical frameworks begin from the implicit assumption that a functioning nervous system already exists and subsequently attempt to explain how neural activity gives rise to perception, cognition, and behavior. Representational theories (Marr, 1982), internal models (Wolpert, Ghahramani, & Jordan, 1995; Wolpert & Kawato, 1998), predictive coding (Rao & Ballard, 1999; Friston, 2005, 2010), Bayesian approaches (Knill & Pouget, 2004; Clark, 2013), neural manifold frameworks (Gallego et al., 2017; Saxena & Cunningham, 2019), dynamical systems theory (Kelso, 1995), and contemporary accounts of large-scale brain dynamics (Pessoa, 2022) differ substantially in their proposed mechanisms, yet ultimately share the same fundamental assumption: the primary organization of cognition is located within the brain. The external world provides the physical input, whereas the nervous system provides the cognitive organization.

Over the past decades, neuroscience has progressively moved away from linear information-processing architectures toward descriptions emphasizing recurrent connectivity, large-scale feedback networks, traveling waves, neural manifolds, representational drift, and distributed coordination across widespread neural populations (Kelso, 1995; Buzsáki, 2006; Churchland et al., 2012; Gallego et al., 2017; Saxena & Cunningham, 2019; Pessoa, 2022). Simultaneously, ecological psychology (Gibson, 1979), ecological neuroscience, embodied cognition, enactivism (Varela, Thompson, & Rosch, 1991; Hutto & Myin, 2013), and dynamical systems approaches have increasingly emphasized the continuous coupling between organism and environment. Despite these important conceptual developments, however, the brain has remained the unquestioned locus of cognitive organization. This assumption immediately raises a more fundamental evolutionary question. If the brain constitutes the primary organization of perception and cognition, how did such an extraordinarily coherent internal organization arise during evolution? More fundamentally, what organized the nervous system itself before it could organize anything else?

The answer begins long before the evolution of nervous systems. From an evolutionary perspective, the causal sequence appears to be precisely the opposite of that assumed by contemporary cognitive neuroscience. Billions of years before the first neurons or brains evolved, the Earth already consisted of a richly organized physical world. Electromagnetic radiation propagated according to the laws of physics, sound waves travelled through material media, mechanical forces continuously governed interactions between objects, chemical gradients formed and dissipated, temperature gradients evolved across space and time, and gravity continuously constrained every possible movement. These externally specified physical dynamics unfolded as uninterrupted spatiotemporal sequences in which each state necessarily emerged from the preceding state while simultaneously constraining the next. Consequently, the external surfaces of evolving organisms were continuously exposed to adjacent temporal units of an already organized physical world. Organisms therefore evolved within pre-existing external organization rather than constructing that organization through neural computation.

This evolutionary sequence introduces a fundamental asymmetry. The external world preceded the nervous system not only temporally but also organizationally. The physical dynamics to which organisms continuously adapted throughout evolutionary history were not generated by nervous systems;

rather, they constituted the very conditions under which sensory receptors, specialized sensory organs, and eventually nervous systems evolved. Consequently, the primary organization of perception and cognition cannot simply be assumed to originate within the brain. The more fundamental question is where this pre-existing external organization first becomes biologically available to the organism.

The answer follows directly from the causal sequence itself. The external world can influence an organism only through physical interactions at its sensory surface. Every photon reaches the retina before visual neural activity can occur. Every sound wave first produces mechanical displacements within the cochlea before auditory activity begins. Mechanical forces are first registered by receptors in the skin, muscles, tendons, and joints before somatosensory processing occurs. Likewise, chemical substances, temperature changes, vestibular accelerations, proprioceptive changes, and interoceptive signals all first encounter specialized sensory receptors before any neural activity can arise. Every instance of neural activity is therefore necessarily preceded by an externally specified physical interaction at the sensory surface.

Throughout this article, the term *sensory surface* refers to the complete functional interface at which continuously changing externally specified physical dynamics directly encounter the organism. It does not simply denote a collection of sensory receptors or an anatomical boundary, but the only location where organism and environment come into direct physical contact. The sensory surface is therefore the point at which the externally organized dynamics of the physical world first become biologically available.

This seemingly simple observation has profound theoretical consequences. If every externally generated event necessarily reaches the sensory surface before any neural activity can occur, then the primary organization of cognition cannot logically originate within the brain alone. The organization of the external world is not imposed upon sensory stimulation by neural computation; it reaches the organism already as continuously organized spatial and temporal dynamics. The present article therefore proposes that the primary organization of cognition resides at the sensory surface, whereas the brain functions as an evolutionarily developed biological stabilization system that preserves, coordinates, and optimizes this ongoing organism–environment relationship.

The Sensory Surface as the Primary Locus of Cognitive Organization

The evolutionary asymmetry outlined in the previous section has profound implications for where the primary organization of cognition should be sought. If the externally specified dynamics of the world were already fully organized before nervous systems evolved, and if every interaction between organism and environment necessarily begins at the sensory surface, then it is far from self-evident that the primary organization of cognition originates within the brain. The central question therefore shifts from how the brain processes sensory information to where the already organized dynamics of the external world first become biologically available to the organism.

Within the dominant theoretical frameworks, this question is generally answered only implicitly by treating the sensory system primarily as a mechanism for sensory transduction. The retina converts electromagnetic radiation into neural activity, the cochlea converts sound waves into electrical signals, and specialized receptors transform mechanical, chemical, or thermal energy into action potentials. From this perspective, the sensory system merely functions as a gateway to the brain, whereas the actual organization of perception and cognition is assumed to emerge during subsequent neural processing. The sensory surface is therefore assigned a peripheral role, while the brain is regarded as the central organizing system.

This interpretation, however, is not a necessary consequence of the biological evidence. Sensory transduction does not create the organization of the external world; it merely converts an already organized physical dynamic into a biological process. The spatial structure of the visual field exists before pho-

tons reach the retina. The temporal structure of sound exists before acoustic waves reach the cochlea. Mechanical interactions between organism and environment are already physically specified before they activate receptors in the skin, muscles, or tendons. The same applies to chemical concentration gradients, temperature changes, vestibular accelerations, proprioceptive changes, and interoceptive processes. Sensory receptors do not impose organization upon these dynamics; they simply constitute the biological interface through which this pre-existing organization reaches the organism.

From this perspective, the *sensory surface* acquires a fundamentally different theoretical status. It is not merely the periphery of the nervous system, but the functional interface at which the externally specified dynamics of the world continuously encounter the organism. It is the only location where organism and environment come into direct physical contact. Every instance of neural activity is necessarily preceded by an already structured interaction at this interface. The causal sequence is therefore not neural organization followed by perception, but externally specified dynamics, sensory specification, and only then neural stabilization.

This causal sequence has important implications for the interpretation of perception itself. Within traditional cognitive neuroscience, perception is generally regarded as the outcome of neural computations performed on sensory input. In the present framework, by contrast, perception is understood as the continuously organized interaction between the externally specified dynamics of the world and the *sensory surface* upon which those dynamics are projected. The primary organization of perception therefore resides not in the neural activity that follows this interaction, but in the organization of the interaction itself. The brain does not receive unstructured input that still requires organization; rather, it receives a sensory dynamic that is already spatially and temporally organized and subsequently stabilizes it biologically.

This reinterpretation also changes the functional significance of the nervous system. The present framework does not diminish the extraordinary complexity of the brain; instead, it assigns that complexity a different evolutionary function. Organisms are continuously confronted with simultaneously changing visual, auditory, haptic, proprioceptive, vestibular, olfactory, gustatory, and interoceptive dynamics that together constitute a single, continuously evolving organism–environment relationship. The principal evolutionary challenge is therefore not to construct this organization, but to preserve its stability despite the continuous changes occurring in both the organism and its environment. From this perspective, the brain emerges as a biological stabilization system that preserves, coordinates, and optimizes the coherence of this ongoing sensory dynamic.

This interpretation also provides an alternative perspective on a wide range of findings in contemporary neuroscience. The extensive recurrent architecture of the cortex, the predominance of feedback pathways, large-scale synchronization, traveling waves, rotating waves, neural manifolds, representational drift, and distributed neural dynamics need not primarily be interpreted as mechanisms by which the brain constructs perceptual content. Instead, they can be understood as mechanisms through which the nervous system continuously stabilizes the coupling between ongoing sensory dynamics and previously established neural residues, thereby maintaining the coherence of the organism–environment relationship over time.

If this interpretation is correct, the central question of cognitive neuroscience must fundamentally change. The principal challenge is no longer to explain how the brain constructs cognition from sensory input, but to understand how the already externally specified dynamics of the world become organized at the *sensory surface*, and how the nervous system subsequently stabilizes this continuous interaction. From this perspective, the *sensory surface* becomes the primary locus of cognitive organization, whereas the brain emerges as an evolutionarily later, yet indispensable, stabilization system that supports this organization without originally creating it.

The Gramophone Model: The Brain as a Biological Stabilization System

If the primary organization of cognition resides at the *sensory surface*, an immediate question follows: what, then, is the primary function of the brain? Within most contemporary theories, neural activity is assumed to construct, infer, predict, or represent perceptual reality from sensory input. The perspective developed in the preceding sections suggests a fundamentally different interpretation. If externally specified physical dynamics already possess their relevant spatial and temporal organization before neural activity begins, then the principal evolutionary role of the nervous system is unlikely to be the construction of that organization. Rather, its primary function is to preserve, stabilize, coordinate, and continuously optimize an organization that already exists at the sensory surface.

The theoretical framework developed in this article to formalize this interpretation is referred to as the Gramophone Model (GM). The model derives its name from a simple physical analogy that illustrates the causal relationship between externally specified dynamics and neural organization. During the recording process, sound waves produce grooves within the surface of a gramophone record. These grooves do not contain sound, nor do they constitute an internal representation of the original acoustic event. Instead, they preserve the physical consequences of previous interactions between externally generated sound waves and the recording surface. When the record is subsequently played, these previously formed grooves constrain the movement of the needle, allowing a corresponding acoustic structure to re-emerge. The grooves therefore represent neither sound nor meaning, but the causal history of earlier interactions with externally specified dynamics.

According to the GM, the relationship between the sensory surface and the nervous system follows the same fundamental principle. Throughout life, continuously changing externally specified dynamics repeatedly interact with the sensory surface. These interactions leave enduring traces within neural tissue that are referred to here as neural residues. Importantly, these neural residues do not contain the external world, nor do they constitute internal copies or representations of sensory experience. Rather, they embody the accumulated consequences of previous organism–environment interactions. Every new sensory interaction therefore occurs against the background of an increasingly structured neural system whose organization has itself been shaped by earlier externally specified dynamics.

Within this framework, perception is not reconstructed inside the brain. Instead, externally specified dynamics continuously organize perception at the sensory surface, while previously established neural residues contribute to the stabilization of that ongoing interaction. Neural activity is therefore understood as a dynamic stabilization process rather than as the generation of perceptual content. The function of the nervous system is to maintain coherence across continuously changing sensory interactions, to coordinate simultaneously active sensory modalities, to compensate for inevitable deviations arising during perception and action, and to integrate current sensory dynamics with the accumulated consequences of previous experience.

This reinterpretation also provides an alternative functional explanation for the remarkable anatomical organization of the vertebrate brain. The extensive recurrent architecture of the cerebral cortex, the overwhelming predominance of feedback pathways, the continuous synchronization of distributed neural populations, traveling waves, rotating waves, neural manifolds, representational drift, and large-scale cortical coordination become understandable as complementary mechanisms serving a common biological objective: the stabilization of continuously changing externally specified dynamics. Rather than constructing perception, these mechanisms preserve the coherence of an organism whose relationship with the environment is necessarily dynamic, multidimensional, and continuously evolving.

The concept of neural residues likewise acquires a different theoretical significance. Within traditional representational frameworks, long-term neural changes are generally interpreted as stored internal knowledge about the external world. Within the Gramophone Model, however, neural residues are un-

derstood as the accumulated biological consequences of previous sensory interactions. Their functional role is not to reproduce the world internally, but to enable increasingly stable interactions with future externally specified dynamics. Memory therefore becomes fundamentally prospective rather than retrospective. Earlier interactions continuously contribute to the stabilization of subsequent interactions without constituting internal representations of the external world itself.

This stabilization perspective also offers a coherent interpretation of cognitive development and evolution. Nervous systems did not evolve because organisms first required internal representations of reality. Rather, increasingly complex nervous systems became necessary because increasingly complex organism–environment interactions required progressively greater stability, coordination, and adaptability. Evolution therefore proceeded from externally specified physical organization toward increasingly sophisticated biological stabilization systems. The brain represents the current outcome of this evolutionary process, not its origin.

The remainder of this article develops this stabilization framework across multiple domains of cognition. Subsequent sections examine its implications for perception, action, memory, neural organization, and consciousness, and compare its explanatory power with representational theories, predictive coding, internal model frameworks, ecological psychology, and recent developments in systems neuroscience. Throughout the article, the central thesis remains unchanged: cognition is primarily organized at the *sensory surface*, whereas the brain functions as an evolutionarily developed stabilization system that continuously preserves and optimizes the ongoing relationship between organism and the externally specified dynamics of its environment.

Chapter 1

The Gramophone Principle

1. The Gramophone Principle as a Physical–Ecological Analogy

The Gramophone Model[1] (GM) derives its name from the physical principle of the gramophone, not as a historical curiosity, but as an exemplary model of non-representational transduction. In the recording of a gramophone record, temporal variations in air pressure are directly converted, via an acoustic horn, into mechanical displacements of a needle, resulting in a continuous trace of grooves on the surface of the record. Every momentary change in acoustic energy produces a corresponding material differentiation in this trace. The geometric properties of this trace — including depth, shape, and amplitude — correspond directly to the frequency and intensity characteristics of the original sound.

This process requires no interpretation, computation, or abstract representation. It constitutes a direct physical transduction of energy between media. The groove does not function as a code or symbol, but as a persistent material residue of the sound event itself: a fixed temporal dynamics. During playback, no information is "retrieved"; rather, it is again a physical process in which the existing material structure is converted, via needle and horn, into acoustic vibration. Recording and playback thus form two complementary phases of one and the same continuous physical process and are themselves strictly analogous processes of energy transformation.



Although the gramophone, as an early mechanical recording medium, was associated with considerable energy losses, the principal point remains that recording and playback do not constitute separate processes, but two complementary phases of a single continuous physical transformation process. Energy is neither stored nor interpreted but only transformed into another form. The groove is not a code, representation, or information carrier, but a material differentiation that arises directly from the interaction between external dynamics and the properties of the medium. In itself, the groove has no meaning; apart from the medium and the corresponding transduction process, it is merely an abstract geometric structure. Meaning arises only when this structure re-enters the same physical process in which it was formed.

[1] The GM has previously also been referred to as the Telephone Model, reflecting the idea of a telephone conversation in which one simultaneously functions as both speaker and receiver.

The GM proposes that a physically analogous principle applies to biological systems, with the essential difference that recording and feedback do not occur sequentially but simultaneously. Through the senses, new temporal traces are continuously formed in internal neural dynamics, while this same dynamics simultaneously participates, via efferent feedback, in ongoing perception. Incoming sensory activity is therefore not passively registered but immediately confronted with pre-existing internal dynamics shaped by prior interactions with similar external structures. Recording and feedback thus do not constitute separate steps, but a single integrated process in which external dynamics is internally continued within the same temporal frame.

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2. The Gramophone Model and the Brain

In organisms, the gramophone process does not unfold sequentially but simultaneously. Recording and feedback coincide within one and the same temporal unit. When a new stimulus reaches the senses, it is immediately confronted with the internal "groove" that most closely corresponds to it. The external input is, as it were, cast into pre-existing neural patterns and overlaps with residues of prior perception. This gives rise to a direct feedback loop in which afferent inflow and efferent feedback do not constitute separate signals, but together form a single continuous dynamic process, such that comparison does not occur after perception but within perception itself.

This comparison does not involve cognitive computation, but a physical overlap response in which the current stimulus resonates with prior temporal similarities. Within this framework, the brain does not need to interpret or compute and can be understood as an analogous comparison medium. Each new stimulus activates only those previously formed, temporally anchored patterns whose physical structure most closely matches the current input. The stimulus is neither supplemented nor enriched; only pre-existing overlap is actualized. In this process, the brain adds nothing to the world, but merely actualizes what is reactivated by external dynamics. This process is comparable to the playback of a gramophone record, in which an existing groove reproduces a previously established vibrational dynamics without modifying it.

Within this framework, the brain does not function as an interpretive, computational, or predictive system. Instead, it operates as a stabilizing and resonant medium in which new sensory dynamics connect to existing temporal traces. These traces are not representations of the world, but physically anchored residues of prior similar interactions with the world as they are projected onto the senses. Their activation does not constitute an addition to the current stimulus, but an immediate continuation and stabilization of an already existing temporal structure.

Perception therefore necessarily manifests as partial recognition. Each new perceptual event is inherently unique, yet at the same time grounded in the reactivation of previously established temporal structures. The current sensory input and the activated internal continuation coincide within a shared temporal frame and together form a single continuous perceptual field, comparable to the simultaneous resonance of multiple sources of vibration. The fact that perception is never entirely novel does not reflect a cognitive limitation but follows from the fundamental temporal continuity of physical interactions between organism and environment.

This simultaneous structure of recording and feedback forms the basis for all further organization of perception and action within the GM. It renders internal representations, inferential processing, and predictive computation unnecessary in principle and definitively positions the brain as a medium: not as a source of organization, but as the locus where external dynamics is continued, amplified, and stabilized over time.

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3. Conditionality of Implementing the Gramophone Model: Perceiving External Organization

Although the GM does not require additional assumptions about internal representation or organization, its validity is not independent of how the external world is understood and investigated. The model assumes no more than what is physically necessary, but it does require that the structuring forces in the environment that organize perception and action are explicitly identified and analyzed. As long as these structures are not perceived or recognized as such, there is nothing to couple to, nothing to mediate through sensory transduction, and nothing to internally continue or stabilize.

The GM does not shift explanatory burden from the brain to another internal mechanism, but to external dynamics themselves. It therefore becomes operational only when the environment is no longer treated as a set of discrete stimuli, but as a structured, law-governed, temporally organized domain. Action trajectory shapes, temporal closures, continuities, and constraints in movement are not secondary features; they constitute the primary input for perception and action. If this external organization is not identified, sensory input remains underdetermined, and the brain is incorrectly reinstated as the central source of explanation.

In this sense, implementing the GM is not primarily a technological or neural challenge, but a perceptual–analytical one. The key step is learning to detect the lawful structures already present in the environment: the dynamics that constrain action, delimit possibilities, and specify temporal unfolding. Only when these structures are made explicit—empirically, analytically, and experimentally—does it become clear how little the brain itself needs to organize. The role of the brain can then be reduced to what it is within the GM: mediating, continuing, and stabilizing externally specified dynamics.

This also clarifies why existing approaches repeatedly invoke internal models and inference. Not because they are necessary, but because the relevant external structure has not been explicitly identified. When the environment is treated as structurally impoverished, organization must be assumed to occur internally. The GM, in contrast, holds that this internal emphasis disappears once external organization is properly described. The shift of explanatory weight from brain to environment is therefore not a theoretical preference, but an empirical consequence.

The following sections develop this condition explicitly. The focus shifts from internal mechanisms to the analysis of external action trajectory shapes, temporal parameters (including *tau*-structures), and the way cortical dynamics track and mediate this external organization. Implementation of the GM thus begins not in the brain, but in learning to perceive what the environment already specifies.

Chapter 2

The Evolutionary Genesis of the Brain and The Gramophone Model

1. The emergence and nature of stimuli

Light and darkness, temperature differences, pressure gradients, phase transitions between water, earth, and air, as well as sounds and odors, have been intrinsic physical entities of the world since the formation of the Earth. The intensity of these phenomena varied across time units, such that no moment was identical to the previous one, yet remained structurally similar within a physically consistent and evolving world (Prigogine, 1980; Nicolis & Prigogine, 1977). Movement did not arise as an additional phenomenon, but as the direct and necessary consequence of inequalities in energy distribution across successive time units (Feynman e.a., 1963).

Because time itself constitutes a constant physical dimension, changes in movement are necessarily linked. Changes do not occur in isolation but form temporal sequences: chains of adjacent time units in which matter, energy, and motion continuously transition between states, each state emerging from the preceding one (Einstein, 1905; Smolin, 2013). This temporal coupling is not a secondary property of the world, but a direct consequence of the continuity of time within physical reality.

So, from its origin, the world therefore existed as an uninterrupted sequence of strictly ordered events unfolding over time. These events never repeated identically, yet exhibited structural similarity within a stable, law-governed world (Whitehead, 1929; Nicolis & Prigogine, 1977; Prigogine, 1980). Repetition in form without identity in instantiation thus constitutes a fundamental feature of natural dynamics.

With the emergence of organic life, these worldly entities did not change in nature but were extended by new forms of movement and interaction. Living systems entered into interaction both with each other and with the original material of the Earth, thereby incorporating biological processes into the same temporal and energetic dynamics that already existed (Schrödinger, 1944; Deacon, 2011). Life did not introduce new physics, but a new mode of participation in existing physical processes.

Each living organism was therefore confronted, at every moment in time, with a continuously renewed set of stimuli—never identical, yet recognizable in form and progression—arising from the ongoing interaction between external energy changes and the temporal structure of the environment (Gibson, 1979; Buzsáki, 2006). This regularity within change forms the necessary condition for stability in perception and behavior.

These stimuli are therefore not interpretations, not signals in a cognitive sense, and not constructions of a perceiving system, but actual physical events that are temporally specified and have direct material consequences. Their effects occur inevitably once organism and environment come into physical contact. Affordances arise only secondarily, as relational possibilities for action, and are not constitutive of the occurrence of the stimulus itself (Gibson, 1979). Stimulating influences thus form a contin-

uous, causal, and physically necessary process unfolding within the actual ordering of time, independent of the complexity or level of organization of the perceiving system.

2. The Emergence of External Receptors

The emergence of external receptors in living organisms is therefore not a contingent innovation or a goal-directed adaptation, but a physically inevitable consequence of the continuous influence of light, heat, pressure, sound, and chemical composition in the environment (Arendt e.a., 2008; Lamb, 2011; Nilsson, 2009). Organic structures exposed to such conditions could not but enter into interaction, as physico-chemical interactions between energy and matter necessarily lead to structural change (Schrödinger, 1944; Deacon, 2011).

In the earliest stages, these sensitivities took the form of microscopic zones on the cell surface in which the material organization differed from the surrounding structure (Arendt e.a., 2008; Kandel e.a., 2021). These zones responded directly to specific forms of external energy. A slight change in light could alter the configuration of a pigment molecule, as in rhodopsin in early photoreceptors, thereby producing an electrical response in the cell membrane (Lamb & Pugh, 2006; Nilsson, 2009). Differences in pressure affected the mechanical tension of the cell wall and could open ion channels, a mechanism also found in contemporary mechanoreceptors (Gillespie & Walker, 2001; Hamill & Martinac, 2001). Chemical variations led to molecular binding at the cell surface, giving rise to the first forms of chemical and olfactory transduction (Buck & Axel, 1991; Ache & Young, 2005).

These responses were entirely local and immediate: stimulus in, response out (Kandel et al., 2021). Once the external stimulus ceased, the internal response also disappeared. There was no interpretation, memory, or internal representation, but only direct physical transformation of external energy into internal change, as is also observed in simple unicellular organisms without a nervous system (Naitoh & Eckert, 1974; Buzsáki, 2006).

These sensory zones constituted the first boundary interfaces at which outside and inside met and thus functioned as the initial material interfaces where the temporal structure of external dynamics was continued internally (Gibson, 1979; Deacon, 2011). They did not form a separate system, but rather a necessary component of the same physical dynamics in which organism and environment were from the outset interconnected (Whitehead, 1929; Schrödinger, 1944). At this stage, perception existed solely as a direct coupling between external variation and internal response, without storage, comparison, or anticipation (Buzsáki, 2006; Kandel e.a., 2021).

3. From External to Internal Continuation

With the emergence of external receptors (sensory zones), the internal continuation of worldly dynamics became physically inevitable. The world exists as continuous change over time; every change that affects an organism is internally continued for as long as that external dynamics persists and the internal state of the organism physically permits it (Prigogine, 1980; Whitehead, 1929; Smolin, 2013).

External stimuli are not discrete events with a beginning and an end, but ongoing worldly processes that vary from moment to moment. Light, pressure, chemical gradients, and mechanical tensions exist only as unfolding dynamics; what appears as a "new stimulus" is always a subsequent state within the same temporal trajectory (Nicolis & Prigogine, 1977; Feynman e.a., 1963; Gibson, 1979).

The internal activity that arises in organisms is not a response to an isolated stimulus, but a physical co-movement with a continuous external dynamics. What changes externally changes internally in parallel — not as a representation or internal image, but as a direct continuation of the same event within a different physical medium (Schrödinger, 1944; Deacon, 2011; Heeger, 2017). This continuation is

strictly causal: external stimuli give rise to internal dynamics, but do not transfer content, structure, or worldly properties — as explicitly formulated within the GM (Gibson, 1979; Bickhard, 2009; Hutto & Myin, 2013).

That certain forms of external energy, such as heat, can penetrate more deeply into an organism does not constitute an exception but rather a side condition. Thermal transfer likewise does not result in the internal continuation of worldly structure, but in local changes in kinetic energy and molecular motion that are subsequently regulated internally (Callen, 1985; Schrödinger, 1944; Kittel & Kroemer, 1980). The same applies to chemical diffusion: external molecules may come into physical contact with the organism, but their worldly organization is not preserved internally; they function only as causal triggers for autonomous internal dynamics (Laughlin e.a., 2000; Deacon, 2011; Bray, 2009).

This direct coupling between external and internal movement is empirically observable in simple organisms without a specialized nervous system, such as *Paramecium* and *Euglena*, where orientation to light and chemical gradients occurs without central processing. In these systems, sensory change and motor change do not constitute separate processes, but different phases of a single continuous temporal dynamics (Naitoh & Eckert, 1974; Jennings, 1906; Buzsáki, 2006).

The internal activity that follows from this does not constitute storage nor a momentary reaction, but a continuously fluctuating internal state that necessarily arises from the electrochemical nature of living matter. Biological membranes maintain persistent inequalities in ion distribution, such that electrical potentials and ionic currents continuously vary under the influence of ongoing external change (Hodgkin & Huxley, 1952; Buzsáki, 2006; Kandel e.a., 2021).

The neuronal process did not emerge in order to detect or represent discrete stimuli, but because biological structures physically permitted continuous external change to be internally continued as structured electrical dynamics over time. Electrical impulses do not constitute discrete responses, but temporally organized phases within an already ongoing electrical dynamics (Freeman, 2000; Heeger, 2017; Deacon, 2011).

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4. The Structural Separation and Necessary Coupling Between Sensory Interface and Internal Continuation

The preceding analysis clarifies that the sensory interface and internal continuation are not variants of one and the same process, but structurally distinct domains within a single continuous causal chain. The input to the sensory interface is fully autonomous with respect to the input from the sensory interface to the organism: the world delivers its dynamics independently of the organism, while the continuation of that dynamics within the organism constitutes a separate internal physical process. These domains are necessarily causally connected, but share no substance, structure, or content (Whitehead, 1929; Gibson, 1979; Bickhard, 2009).

The external world, and the previously identified fundamentally present, physically real conditions from which external stimuli arise, exists as continuous movement over time and interacts with the organism only at its surface. The sensory interface therefore does not constitute an extension of internal processes, but the sole physical boundary at which this worldly dynamics can act upon the organism. What reaches the sensory interface is not determined by the body or the brain, but by the autonomous dynamics of the world itself (Gibson, 1979; Chemero, 2009).

Within this framework, sensory transduction is an autonomous process. It transforms external dynamics — light, pressure, chemical gradients, and mechanical change — into internal dynamics but transfers no element of the external substance. What arises internally is not light, not sound, and not smell, but a new physical phenomenon: electrical and ionic activity within a closed internal medium. The re-

lation between external and internal is therefore strictly directional and temporal, not material or content-based (Marr, 1982; Buzsáki, 2006; Freeman, 2000).

This implies that the internal residue resulting from sensory transduction has, in principle, no access to the world. The internal process has no access to light, sound, smell, or any other form of worldly dynamics, but operates solely within its own physical domain. Any assumption that the brain itself perceives, interprets, or represents therefore implicitly presupposes the existence of a second sense — an internal instance that would see, hear, smell, etc.. Such an assumption is structurally untenable, as the internal system is necessarily separated from the world and can only continue it through causal transformation (Ryle, 1949; Bickhard, 2009; Hutto & Myin, 2013).

The widespread assumption that perception takes place internally thus rests on a fundamental confusion of domains. Sensory systems detect worldly change; internal processes resonate with and continue this change within their own medium. The brain does not see, hear, or smell — and cannot do so, because it is never in direct physical contact with worldly phenomena. Perception is not an internal construction, but a relational process that necessarily unfolds at the boundary between world and organism (Gibson, 1979; Noë, 2004; Hutto & Myin, 2013).

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5. The Ecologically Constrained Internal Continuation: Brain Formation, Regulation, and Feedback Loops

The structural separation between sensory interface and internal continuation implies that internal processes had to emerge under ecological constraint. The continuous accumulation of internal residue — as a result of uninterrupted sensory transduction — necessarily gave rise to increasingly complex internal dynamics. These dynamics resulted, as empirically observable consequences, in the formation of internal organs (including a brain) alongside regulatory systems for motor control, energy balance, tissue condition, temperature, metabolism, and repair (Schrödinger, 1944; Sterling & Eyer, 1988; Deacon, 2011; Cannon, 1932).

Within this framework, evolution did not produce goal-directed progress, but constrained change: variants that enabled internal coherence and continuation under ecological pressure were retained, while others disappeared (Darwin, 1859; Mayr, 1982). Internal organs therefore did not develop as perceptual instances, but as regulatory structures coordinating internal dynamics. The brain emerged as an internally organizing medium that stabilizes temporal coherence among simultaneously active internal processes under continuous external pressure (Buzsáki, 2006; Pessoa, 2022; Freeman, 2000).

In this role, the brain does not function as a center of perception, but as a nexus of internal continuation, where sensory translations, autonomic regulation, emotional configurations, and action dynamics converge. Emotions, in this framework, are not interpretations of stimuli, but global organizational states that position the organism with respect to expected ecological demands and internal stability (Damasio, 1994; Sterling, 2012; Panksepp, 1998).

This development was necessarily accompanied by the emergence of feedback loops. Internal configurations that contributed to temporal continuity, energetic efficiency, and behavioral coordination were structurally reinforced. Feedback does not function as cognitive evaluation, but as physical recursion: dynamic patterns that promote internal stability persist and are re-enacted (Ashby, 1956; Buzsáki & Draguhn, 2004; Kelso, 1995).

Within this framework, allostatic regulation also emerges. Allostasis refers to the capacity of an organism to proactively organize internal states in anticipation of ongoing external change. Fear, hunger, fatigue, and arousal are not representations of the world, but bodily organizational states that prepare

internal dynamics for expected ecological demands (Sterling & Eyer, 1988; Sterling, 2012; Barrett, 2017).

The brain thus did not evolve to know the world, but to maintain the internal coherence of the body while worldly dynamics continue to unfold outside the organism. It remains entirely internal, without direct access to those dynamics, yet under continuous causal influence through sensory transduction. Sensory systems and the brain therefore evolve autonomously while remaining structurally coupled through constraining feedback loops (Gibson, 1979; Deacon, 2011; Hutto & Myin, 2013).

The essential point is that no internal organ — including the brain — ever assumes a sensory function. Sensory systems remain where they are ecologically necessary: at the surface, in direct contact with worldly dynamics. Internal organs exclusively organize the internal continuation and regulation of those dynamics. What emerges is a system composed of an autonomous world, autonomous sensory interfaces, and autonomous internal dynamics, connected through causal translation and reciprocal, yet strictly non-representational, feedback.

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6. Conclusion: The Gramophone Model as a Maximally Ecological Account

The preceding analysis demonstrates that the GM does not introduce an additional theoretical construct but formalizes the necessary consequence of a world that already exists as temporally structured physical dynamics. External phenomena — light, pressure, temperature gradients, chemical gradients, and mechanical tensions — constitute the factual and constraining conditions under which life had to develop. These phenomena do not offer unlimited possibilities but define a bounded spectrum of physically realizable interactions.

Within this spectrum, only that which was strictly permitted by these external conditions could emerge. Biological variation unfolds within material and energetic constraints already specified by worldly dynamics. In Darwinian terms, only those configurations capable of maintaining stable interaction with these external processes persist; what does not conform to the available physical structure cannot be sustained.

It follows that sensory transduction and internal regulation not only could arise but had to arise under continuous external variation in order to maintain temporal continuity of the organism. Evolution therefore operates strictly within the bounds of what is physically possible and ecologically viable. Nothing can emerge beyond what is allowed by these external conditions.

Under these bounded yet constraining conditions, it follows that at each moment in time not discrete stimuli, but a single integrated, continuously changing configuration of external stimuli reaches the entire sensory surface. This configuration simultaneously encompasses all sensory modalities and spans the entire body as a sensory boundary interface. External stimuli therefore never occur in isolation but always form part of a coherent dynamics in which all forms of physical interaction are co-present. This is not an intermittent delivery of inputs, but a permanent physical condition: external dynamics continuously impinges upon the organism as an integrated whole. This ongoing exposure is not an interpretative category, but a material reality.

A crucial consequence follows from this integrated sensory organization: isolating a single sensory modality as if it independently organizes behavior can become theoretically misleading. In natural perception, organisms are never confronted with isolated visual, auditory, haptic, proprioceptive, or vestibular stimuli, but with a continuously integrated spatiotemporal configuration spanning the entire sensory surface simultaneously. Any explanatory framework that elevates one isolated modality into the primary organizing principle therefore risks overlooking the fundamentally hybrid and co-structured nature of real-world perception–action dynamics.

Organisms therefore necessarily develop as systems that receive and continue this ongoing external variation over time. Because successive temporal states are physically coupled, successive stimulus positions are structurally connected: each state follows from the previous and constrains the next. It is precisely this temporal coupling that gives rise to structure. The resulting line-structure of stimulus progression is therefore not introduced by the organism but follows directly from the continuity of time itself. This continuous line-structure constitutes the essential external organization of perception and action, and it is precisely this structure — grounded in the temporal continuity of physical processes, in line with the fundamental insight of relativity that structure is inseparable from spatiotemporal relations — that has, to date, remained fundamentally unrecognized within the scientific field.

The GM makes this structure explicit. It does not posit internal representations or hypothetical mechanisms but formalizes the minimal causal configuration that could and must arise under given worldly conditions: an autonomous external dynamic, a sensory boundary interface at which physical transduction occurs, and an internal continuation that stabilizes and maintains the temporally structured unfolding of those dynamics without representing it.

In this sense, the GM constitutes a maximally ecological account: it remains strictly within the domain of what is physically given, evolutionarily selectable, and empirically observable. Nothing beyond this can be assumed — and nothing beyond this is required.

Chapter 3

The Mechanistic Operation of the Gramophone Model and the Reordering of Predictive Coding

Introduction

The novelty of the Gramophone Model (GM) lies in its explicit relocation of the primary organizing structure of perception and action: not the brain, but externally specified structure as projected onto the sensory surface constitutes the fundamental organization to which behavior continuously remains coupled. Whereas dominant theories assume that perception must internally be constructed through inference, prediction, representation, or computational transformation, the GM proposes that this organization is already physically present within externally unfolding dynamics themselves.

The primary aim of this chapter is to explicate the mechanistic operation of the GM itself. This operation is developed step by step through the perceptual processes involved in observing an approaching ball trajectory, thereby making visible how perception and action emerge from continuous coupling to externally specified trajectory structure as projected onto the sensory surface. Within this organization, the brain does not prescribe or internally generate the primary structure of perception and action but continuously stabilizes externally unfolding dynamics through afferent–efferent feedback loops.

At the same time, this mechanistic analysis clarifies why the phenomena upon which contemporary predictive-coding theories rely genuinely occur. This chapter therefore distinguishes between two fundamentally different organizations of predictive coding: inferential predictive coding (IPC) and externally specified predictive coding (EPC). IPC refers to the dominant scientific framework in which perception and action are understood as the result of internal inferential processes based on internal models, predictions, and prediction errors. EPC, by contrast, refers to the organization proposed within the GM, in which the same observable phenomena emerge from continuous coupling to already externally specified dynamics.

The mechanistic explanation developed within the GM therefore simultaneously functions as an explanation for the emergence of predictive-coding phenomena themselves: anticipation, error correction, and temporal coordination are shown to genuinely exist, but receive a fundamentally different organization within EPC than within IPC.

This chapter explicates the GM primarily through the perception of a ball within an approaching ball trajectory and secondarily through common motor actions involving approaching environmental objects, such as an approaching car, an approaching foot in a combat situation, and the perception of approaching words within conversation.

In all these cases, externally specified structure manifests itself on the sensory surface as continuously unfolding perceptual dynamics to which behavior necessarily remains coupled. Perception and action therefore do not constitute two separate domains requiring internal coordination, but one continuous externally organized dynamic. Perception–action coupling is thereby reformulated not as an internal coordination problem, but as direct coupling to already existing external structure.

At the same time, this analysis reveals the fundamental limitations of IPC. This framework departs from the assumption that sensory input is inherently incomplete and must continuously be supplemented internally through predictive models, often formalized within Bayesian frameworks in which predictions and prediction errors are assumed to organize behavior. The problem is that such assumptions fail to provide a mechanistically closed explanation for the continuous externally observable structure of concrete actions as they unfold across the sensory surface.

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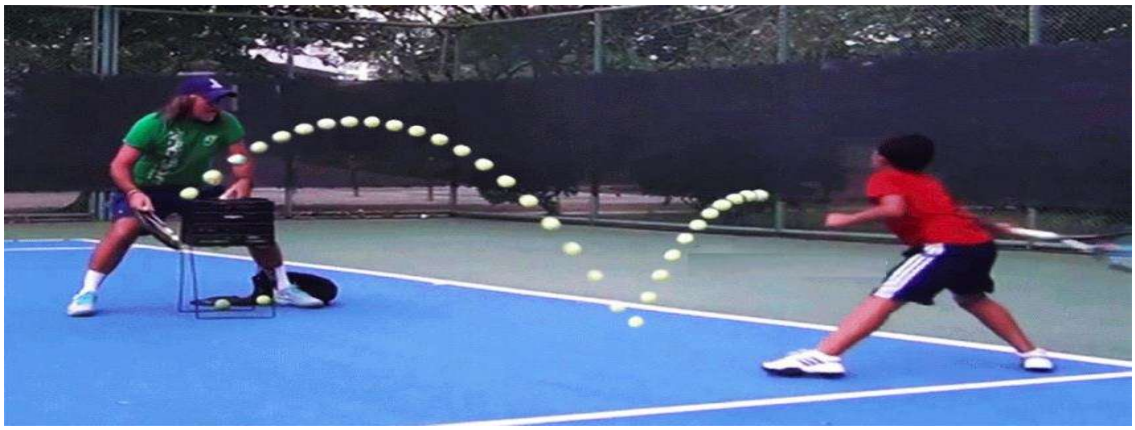
1. The General Perceptual Organization of an Approaching Ball Trajectory Shape

The mechanistic operation of the GM is initially developed through the perception of an approaching tennis ball but applies equally to all catching actions involving moving environmental objects, such as an approaching car, an approaching foot within a combat situation, or the perception of approaching words within conversation. In all these cases, the same fundamental structure unfolds: an externally specified action trajectory shape manifesting itself on the sensory surface as a continuous trajectory structure to which behavior necessarily remains coupled.



Illustrations: *Within spatial dimensions, the movements of every conceivable action object are necessarily constrained within one continuous line structure. Successive positions of the action object must necessarily emerge from preceding positions. The very first isolated position of a ball does not yet specify movement by itself, but nevertheless constitutes the origin point of the action trajectory shape from which the further unfolding of the trajectory must necessarily emerge.*

The perception of the very first position of an action object does not yet specify the further unfolding of the approaching trajectory structure. Nevertheless, this initial position is of fundamental importance within perception, because it constitutes the greatest possible reduction of external reality that can occur within perception itself. Within an almost infinite vista of potential action possibilities, perception is abruptly reduced to one actual position of one specific action object. From that moment onward, the total space of possible movements immediately becomes drastically constrained: all successive positions P of the action object must necessarily emerge from this single position and develop as one continuous line structure. The first position constitutes the beginning of perception and simultaneously the origin point of the entire action trajectory shape.

From this origin point, after only several actual positions of the tennis ball, a perceptual image emerges, as projected onto the sensory surface, of the beginning of the manifest approaching ball tra-

jectory. The actual position P(0) of the ball thereby not only marks the foremost point of the manifest line, but simultaneously the boundary with the still latent unfolding of the trajectory. Because all successive positions of an action object necessarily remain connected, the latent segment must emerge from the manifest segment itself. The action object thereby becomes constrained by the already realized structure: both the shape and the speed of the further movement must necessarily emerge from what has already become manifest.

Illustrations: *The first isolated position (Fig. 1) does not yet specify the movement of the tennis ball. An action object only acquires perceptual meaning in relation to adjacent positions of that object. Nevertheless, this very first position fulfills a fundamental function because it realizes the greatest possible reduction of the perceptual field. From this first actual position onward, successive actual positions P(0) of the ball become continuously coupled on the sensory surface, thereby appearing as one continuous action trajectory shape.*

This leads to a crucial mechanism: based on several manifest positions, a global perceptual image emerges, as projected onto the sensory surface, of the complete trajectory structure, in which the latent segment is not freely constructed, but necessarily emerges from the manifest segment itself. This process can be understood as a marble moving through a marble track: the exact trajectory is not yet fully visible, but the form within which the movement will further unfold is already contained within the manifesting structure itself.

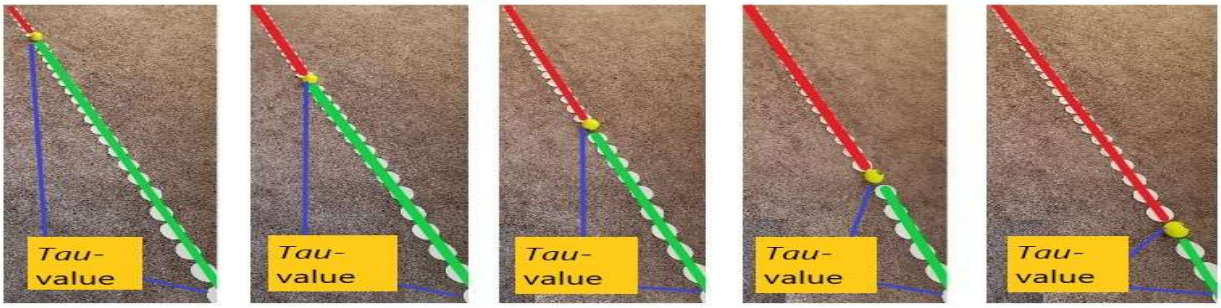
Illustrations: *After only several manifest positions P of the tennis ball, particularly in professional tennis players, it already becomes clear, in a precisely global*[2] *manner, how the latent segment will unfold in both shape and tau-value (time-to-contact). Within the explanatory model of the motoric movement action, the term "precisely global" refers to the fact that the future trajectory can never be specified with absolute precision, while the fluctuation boundaries of its global unfolding can nevertheless already be determined with considerable accuracy at a very early stage of the perceptual process.*

Importantly, this global specification already emerges at a very early stage of the perceptual process. As the analysis demonstrates, both the direction and the speed (*tau*-value) of the entire approaching

[2] *Precisely global* is a term developed within the explanatory model of motor movement action to indicate that the future unfolding of a trajectory can never be specified with absolute precision, while the fluctuation boundaries within which this unfolding will develop can nevertheless already be determined with considerable accuracy at an early stage of the perceptual process.

ball trajectory can already be derived within reliable fluctuation boundaries after only several actual ball positions. Consequently, a tennis player can already, at a very early stage, begin approaching the incoming ball trajectory through an autonomous egocentric action trajectory shape, in which the autonomous movement of the racket face must ultimately form an intersection point with the approaching ball trajectory. This means that the action is not based on predicting isolated future positions, but on a complete trajectory structure that does not yet need to be exact, but already sufficiently precise for the egocentric action to begin.

This essentially describes a fundamental ecological principle: effective action does not require a complete or exact specification of the future development of an environmental object, but an early and sufficiently structured restriction of the field of possible continuations. Perception therefore does not eliminate all uncertainty but constrains it to fluctuation spaces within which action becomes possible and stable. It is precisely this early global specification that allows the egocentric movement to be initiated not reactively, but in direct continuous coupling with the external dynamics themselves.



Illustrations: *EPC demonstrates that perception and action are not organized through the continuous generation of new predictions about isolated future positions of the tennis ball — as assumed within IPC. Instead, from the very earliest stages onward, a perceptual image emerges, as projected onto the sensory surface, of a complete action trajectory shape. Within this organization, the tennis ball and the approaching ball trajectory together constitute one indivisible dynamic structure, comparable to a marble moving through a marble track. Only from this total relation can the tau-value (time-to-contact) acquire meaning and be derived. A marble without a marble track, or a marble track without a marble, possesses no action-relevant meaning whatsoever.*

The action therefore does not emerge from reconstructing or predicting isolated future states, but from timely positioning within an unfolding trajectory structure that already provides directional organization. As the ball trajectory shape further develops, the fluctuation boundaries become progressively refined, causing the initially global alignment to transition into increasingly precise convergence toward the eventual intersection point. The system therefore does not operate from exactness toward action, but from early global alignment toward increasing precision within an already ongoing action.

This explanation elevates the ecological argument to its highest level. There is, however, an important limitation. The system that enables rapid action remains fundamentally a global optimization process. Although perception becomes increasingly precise as the end of the action trajectory shape approaches, establishing absolute factual exactness is not the objective of the system itself[3]. Deviations

[3] https://www.researchgate.net/publication/361025924_Novae_within_the_movement_sciences_-_The_goal_of_the_perception_processes_is_definitely_not_to_unravel_all_exact_positions_of_the_ball_within_an_incoming_ball_trajectory_shape_cq_the_perception_proces?_sg%5B0%5D=qa5phczsfxtnChHsU3c8sUno1yd-gGxR6lei295fXjYbXKLfxSVdb8ybKVIwJGpC03maO_Pyap97LRJwqj2osfcget-gIgMjwmSmQpIwZs.63Gc9UJJBRWi1IizT6pZaMALQQU_5BHEH8pgsy6g2OYMMWxk0STgPx0HlaPqyDnMslt5IMuYX5JxnsKDDAjqhg&_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InByb2ZpbGUiLCJwYWdlIjoicHJvZmlsZSIsInBvc2l0aW9uIjoicGFnZUNvbnRlbnQifX0

relative to the perceptual image of the latent action trajectory shape can therefore continuously emerge and must consequently remain mediated until the very end of the action process itself.

The explanatory model of the motoric movement action attributes the mediation of these deviations to the dorsal and ventral streams. Both streams participate in a continuous reciprocal process in which the actual position P(0) of the tennis ball and the complete approaching ball trajectory shape remain simultaneously available. The dorsal stream operates primarily from the perspective of the actual position of the ball, whereas the ventral stream operates primarily from the perspective of the complete approaching ball trajectory shape. Together, both streams continuously mediate emerging deviations and update the projected trajectory throughout the unfolding action.

Illustrations: *Within EPC, prediction errors constitute a fundamentally different phenomenon than within the classical organization of IPC. New predictions about isolated future positions of the tennis ball are not continuously generated. Instead, a perceptual image emerges at an early stage, as projected onto the sensory surface, of a complete action trajectory shape. The actual future positions of the action object will, however, necessarily deviate from this global unfolding. These deviations — both in shape and in timing — are often barely perceptible within an approaching ball trajectory, yet can and inevitably will emerge at every actual position P.*

This reciprocal process must mediate deviations originating from two autonomous phenomena: the zigzag process and the accordion process. The tennis ball can deviate in shape across the width dimension (y-axis), thereby producing a zigzag pattern within perception. In addition, the ball can deviate temporally along the length dimension (x-axis), thereby producing an accordion pattern within perception.

Whenever an arbitrary deviation is perceived, the cortical streams must immediately ensure that the perceptually projected image is correspondingly updated and instantaneously becomes the new reference point for the further unfolding of the action, as if this adjusted trajectory had always constituted the actual ongoing structure itself.

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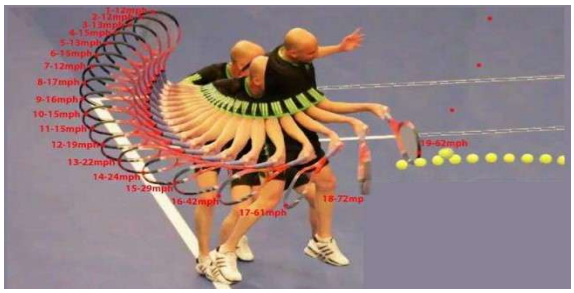
2. The Mechanistic Organization of an Approaching Ball Trajectory Shape within the GM

The general description above of the approaching ball trajectory demonstrates that the structure of the action is fully externally specified. The role of the brain therefore does not lie in constructing this structure, but in stabilizing and continuously maintaining coupling to it as projected onto the sensory surface. With every new actual position P(0) of the ball, the manifest segment of the ball trajectory becomes further extended, while previous positions remain available as residual traces. This residual structure not only concerns the direct unfolding of the manifest ball trajectory itself, but also the residual traces of previous experiences and actions that become superimposed onto the new situation, thereby providing directional organization to the further latent unfolding of the trajectory.

The image projected onto the sensory surface therefore does not remain restricted to the actual position itself but is continuously supplemented by this residual information and by the necessary continuation of the already realized line segment. This supplementation requires no internal calculations or modeling processes but follows directly from the nature of the phenomenon itself: the latent unfolding appears as a continuation of the manifest segment on the sensory surface as this unfolding is continuously prolonged under the combined influence of residual structure and ongoing perceptual input.

This projected latent unfolding can, however, never coincide exactly with the actual development of the ball trajectory, because every new situation is unique and the movement of the environmental object can and inevitably will continuously deviate. The contribution of residual structure therefore does not lie in specifying exact future positions, but in reducing the space of possible continuations, thereby allowing the action to be executed within certain fluctuation boundaries. As the ball trajectory further unfolds, this global specification must progressively become sufficiently precise to allow a successful intersection point to occur with, for example, a tennis racket[4].

This necessary continuous adjustment is mediated by the cortical streams, which continuously regulate the deviations of the actual positions of the ball relative to the projected latent unfolding. Every deviation immediately leads to an adjustment of the image of the manifest segment as projected onto the sensory surface and thereby to a renewed continuation of the projected latent unfolding. This process unfolds within every connected temporal unit and manifests itself in two complementary forms: a spatial correction of the movement (zigzag-process) and a temporal adjustment toward the moment of contact (accordion-process). Both processes operate within direct feedback loops that remain continuously coupled to the projection of the external structure onto the sensory surface, thereby allowing the system to continuously correct itself relative to the actual development of the ball trajectory.



The brain continuously feeds back toward the sensory surface throughout this process, whereby the actual position of the ball, the residual traces of previous positions, and the globally prolonged latent unfolding together form one dynamic unity within which perception and action coincide. The tennis action itself consists of realizing an intersection point between the approaching ball trajectory and the autonomous egocentric movement of the tennis racket, while the brain continuously mediates and stabilizes both the autonomous movement of the ball and the autonomous movement of the racket head through ongoing feedback dynamics. The externally specified structure thereby fully constrains the unfolding of the action. What becomes visible is that the brain is not the organizing source of the action, but the internal stabilizing continuation of an externally specified dynamic in which everything required for the action is already contained within the ball trajectory as it unfolds onto the sensory surface.

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[4] Within a parsimonious ecological organization of perception and action, uncovering the exact factual truth of the unfolding trajectory is never the primary objective of the system itself, because the early stages of the perceptual process only need to provide sufficient directional organization and constrain the field of possible continuations, while precise specification only becomes necessary toward the eventual end-state of the action.

3. Predictive Coding within Contemporary Science

Within this article, a distinction is made between two organizations of predictive coding: inferential predictive coding (IPC) and externally specified predictive coding (EPC). IPC refers to the contemporary scientific framework in which perception and action are understood as the result of internal inferential processes. EPC, by contrast, refers to the organization developed within the GM. The opposition between IPC and EPC therefore does not concern the existence of the underlying phenomena themselves, but their placement within the explanatory framework: whereas IPC situates these phenomena internally, EPC demonstrates that they emerge from continuous coupling to an externally structured and temporally continuous dynamic.

Within contemporary neuroscience, IPC is generally understood as a framework in which the brain continuously generates internal predictions about incoming sensory input. In this approach, sensory information is considered inherently incomplete or ambiguous and must therefore internally be supplemented through inferential processes. The brain is assumed to possess an internal generative model that produces predictions about the causes of sensory input, while discrepancies between predicted and actual input are interpreted as prediction errors that are subsequently used to update the model (Rao & Ballard, 1999; Friston, 2005; Friston, 2010). This approach is closely related to the so-called Bayesian brain hypothesis, in which perception is understood as probabilistic inference under uncertainty (Knill & Pouget, 2004; Clark, 2013).

For the present discussion, it is especially important that IPC primarily localizes the organization of perception and behavior internally. The external world merely provides input, whereas the structural coherence and future development of this input are assumed to be internally constructed by the brain through predictive models and continuous error minimization (Friston, 2010; Clark, 2013). It is thereby implicitly assumed that neural dynamics not only respond to external stimulation, but themselves organize the spatiotemporal structure of behavior.

At the same time, this framework is increasingly confronted with both conceptual and empirical pressure. Multiple authors have pointed out that many empirical findings interpreted as support for predictive coding — such as repetition suppression or anticipatory activity — can also be explained through alternative mechanisms, including neural adaptation or relatively simple dynamical couplings (Summerfield & de Lange, 2014; Heilbron & Chait, 2018). In addition, fundamental criticism has emerged regarding the assumption that neural activity should be understood as a "code" or internal representation of the world itself. Brette (2019), for example, argues that the coding framework remains insufficiently specified to mechanistically explain the relation between neural activity and external structure, and that predictive coding ultimately reformulates rather than resolves the problem of anticipation.

Complementing this critique, ecological and enactivist approaches increasingly emphasize that action-relevant structure is often already directly available within the organism–environment relation itself (Gibson, 1979; Heras-Escribano, 2021). In situations involving the tracking and interception of moving objects — such as an approaching tennis ball — this structure does not appear as a collection of isolated stimuli, but as a continuously unfolding trajectory structure. After only several perceptual moments, a global specification of direction, speed, and possible future intersection already emerges, thereby guiding further perception and action. This aligns with empirical work within the ecological approach to interception and movement control, in which variables such as *tau* provide direct specification for timing and coordination (Lee, 1976; Fajen et al., 2008; van Hof et al., 2004).

Within IPC, however, such trajectory structure is not regarded as primary, but as something that must internally be inferred from sensory input. It is precisely here that the central tension emerges: whereas IPC assumes reconstruction, ecologically inspired approaches demonstrate that the relevant organization of behavior may already be contained within the dynamics of the perceived world itself.

A fundamental difficulty therefore remains unresolved. Although IPC identifies phenomena such as anticipation, error correction, and temporal continuation, it remains unclear how local neural signals themselves generate the continuous externally observable trajectory structure of concrete actions. Internal models and prediction errors thereby function as explanatory postulates, yet without direct empirical specification of how such structures mechanistically carry the organization of behavior itself (Heilbron & Chait, 2018; Brette, 2019). It is precisely at this point that the GM introduces an alternative organization, in which the primary organizing structure is not internally generated, but externally specified within the dynamics as they unfold onto the sensory surface itself.

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4. The Opposition: Inferential Predictive Coding (IPC) versus Externally Specified Predictive Coding (EPC)

The primary objective of this chapter has been to explicate the mechanistic operation of the GM through the perception of an approaching ball trajectory. By developing this mechanistic analysis step by step, it simultaneously becomes visible how the very phenomena upon which predictive-coding theories rely genuinely emerge within perception and action themselves. Anticipation, prediction errors, temporal continuation, and predictive dynamics therefore constitute real perceptual phenomena, but within IPC they are placed within a fundamentally incorrect mechanistic organization.

Within EPC, perception and action are not organized through the continuous inferential generation of predictions about isolated future states of the world. Instead, from the very first manifest positions onward, a global perceptual image emerges, as projected onto the sensory surface, of a continuously unfolding externally specified trajectory structure. This structure already provides directional organization for the further unfolding of both perception and action.

Crucially, this externally specified trajectory structure does not consist of a collection of isolated future projections, but of internally bound trajectory structures in which all successive positions necessarily remain connected. Precisely because the actual and latent segments together form one continuous unfolding structure, an exact relational coupling emerges between shape, speed, direction, and the future intersection point with a possible egocentric action trajectory shape. Within EPC, the action is therefore organized from coherent action trajectory structures that together form one continuous dynamic unity, whereas IPC approaches the future development of the world primarily as a succession of separate predictions about isolated future states.

Illustrations: *Roger Federer must create a future intersection point between the egocentric action trajectory shape of his tennis racket and the approaching ball trajectory structure. To make this possible, he must already almost immediately initiate a running movement toward either the backhand or forehand side of the court. Such an action is only possible because a perceptual image of the global latent unfolding of the approaching ball trajectory already emerges at a very early stage. Without such a global trajectory structure, no perceptual image of the future intersection point could ever arise. Within EPC, this constitutes the central organizational principle: although the perceptual image*

of the approaching ball trajectory remains continuously subject to refinement and correction through cortical mediation, the action itself can already begin from the very earliest stages of the unfolding trajectory.

It is precisely here that a fundamental ecological principle becomes visible. The perceptual image of the action trajectory shape does not yet need to be exact at the beginning of the process, but only sufficiently structured to provide directional organization allowing the action to begin. Within EPC, the egocentric action trajectory shape can therefore already be initiated from the very earliest stages, while the perceptual image of the approaching trajectory structure is progressively refined through the cortical streams as the action further unfolds. The system therefore does not operate from complete precision toward action, but from early global alignment toward increasing precision within an already ongoing action. This progressive transition from early global specification toward later precision constitutes the parsimonious ecological organization through which rapid and successful action becomes possible.

Within IPC, precisely this mechanistic possibility is absent. If perception is understood as a process of continuous inference and the generation of new predictions about isolated future states, no explanation emerges for how an action can already be initiated from the very earliest stages on the basis of a global trajectory structure. If a tennis player could only begin acting once the exact future position of the ball had sufficiently been internally predicted, he would in principle always arrive too late to successfully realize an intersection point with the approaching ball trajectory.

Within EPC, prediction errors therefore do not constitute errors of an internal model of the world, but the necessary deviations between the global perceptual image of the action trajectory structures and their actual further unfolding. Because a global trajectory specification can never coincide exactly with the autonomous dynamics of a moving action object, the cortical streams must continuously update the perceptual image and progressively refine it as the future intersection point approaches.

The GM thereby demonstrates that IPC does indeed identify the relevant perceptual phenomena, but simultaneously localizes their organizing principle in a fundamentally incorrect manner. What appears within IPC as internal prediction, inference, and prediction error instead emerges within EPC from continuous coupling to an already externally specified dynamic in which the action trajectory structures themselves carry the organization of both perception and action.

Conclusion

The opposition between IPC and EPC therefore does not concern the existence of anticipation, prediction errors, or predictive dynamics themselves, but the location of the organizing principle from which these phenomena emerge. Within IPC, these phenomena are interpreted as the result of internally generated inferential processes operating upon incomplete sensory input. Within EPC, by contrast, they emerge from continuous coupling to an already externally specified trajectory structure as projected onto the sensory surface.

The GM thereby proposes a fundamental reorganization of predictive coding itself. What appears within IPC as internal prediction, reconstruction, and inferential completion instead emerges within EPC from the progressive stabilization and refinement of externally unfolding dynamics. The brain therefore does not function as the primary origin of perceptual organization, but as the stabilizing continuation of an externally specified organism–environment dynamic.

Perception and action are consequently no longer understood as two internally coordinated domains, but as one continuous externally organized unfolding in which behavior remains directly coupled to the structure of the world itself.

Chapter 4

The Externally Specified Structure onto the Sensory Interface - The External Structure in Haptic Feedback Processes

Introduction

The first three chapters have developed the mechanistic operation of the Gramophone Model (GM). They have argued that the sensory interface, rather than the brain, constitutes the primary organizing locus of perception, action, cognition, and consciousness. The central hypothesis of the GM is that the structure organizing behavior does not need to be internally constructed but is already present within externally specified dynamics as these are projected onto the sensory surface. The scientific value of this hypothesis ultimately depends on whether this projected structure is indeed capable of autonomously and successfully guiding behavior. Haptic feedback processes provide a particularly suitable domain for examining this proposition because the relationship between external mechanical structure, sensory projection, and behavioral execution is continuously and directly observable.

Within dominant inferential approaches, haptic feedback processes are typically understood as mechanisms through which the brain uses tactile information to construct internal representations or predictions of object properties and bodily relations. Within the GM, this organization is fundamentally reversed. The structure that organizes haptic perception does not arise primarily within the brain, but within the externally specified mechanical dynamics that emerge during organism–environment interaction.

Haptic feedback therefore demonstrates directly that perception and action cannot be understood as separate stages of sensory input, internal processing, and motor output. Changes in force, pressure, grip force, posture, and movement continuously modify both the sensory projection and the further unfolding of the action itself. Haptic feedback thus appears as a continuous perception–action coupling in which external mechanical structure directly constrains, organizes, and modulates behavior.

The following sections examine how this externally specified mechanical structure manifests itself on the sensory interface and how it already contains sufficient organization to guide haptic perception and action without requiring the assumption of an internal reconstruction of mechanical reality.

Although the present chapter analyzes a specific perceptual modality separately, this separation is purely analytical and does not reflect the organization of natural perception itself. Organisms are never confronted with isolated visual, auditory, proprioceptive, haptic, vestibular, olfactory, or other sensory inputs. At every moment, a single continuously changing hybrid sensory configuration is projected onto the entire sensory interface. These sensory dynamics never occur independently, but always emerge as mutually embedded aspects of one externally specified organism–environment relation. The

present chapter isolates one modality solely for explanatory purposes, while recognizing that all perceptual organization ultimately unfolds within this continuously integrated sensory configuration.

1. Haptic Feedback Processes in Contemporary Neuroscience: The Dominant Inferential Interpretation

Within the neuroscientific literature, haptic feedback processes are generally described as a central mechanism of sensorimotor control. When an organism makes physical contact with an object, mechanical interactions such as pressure, shear forces, vibrations, and deformations are registered by specialized mechanoreceptors in the skin (Johansson & Vallbo, 1983; Johnson, 2001), while receptors in muscles and tendons continuously provide information about muscle length, tension, movement, and joint configuration (Sherrington, 1906; Proske & Gandevia, 2012; 2018). According to the dominant interpretation, these afferent signals are integrated with motor commands in order to generate adaptive movement corrections, such that haptic feedback is typically understood as a sensorimotor control loop in which the central nervous system processes sensory information and subsequently organizes motor adjustments (Johansson & Flanagan, 2009; Wolpert & Ghahramani, 2000).

Experimental research on object manipulation has extensively documented the remarkable precision and speed of these processes. When participants lift an object, the forces exerted by the fingers are continuously adjusted to the mechanical properties of the object, including mass, friction, elasticity, and stability (Johansson & Westling, 1984; Flanagan & Wing, 1997). For example, when an object turns out to be heavier than expected, grip force increases almost immediately, whereas incipient slip leads to rapid and often automatic changes in finger pressure and muscular stabilization. These corrections frequently occur within only a few tens of milliseconds and indicate an almost continuous regulation of behavior.

Remarkably, it is precisely these empirical observations that already reveal the operational structure central to the GM. In virtually all haptic experiments, the regulation of behavior is directly constrained by the mechanical properties that emerge within the interaction between organism and object. Mass, friction, elasticity, geometry, resistance, and compressibility continuously determine which forces can arise, which movements remain possible, and which corrections become necessary. At the same time, sensory feedback registers these ongoing changes almost immediately, such that the unfolding sensorimotor dynamics closely track the externally structured mechanical organization of the interaction itself.

Despite these empirical observations, the dominant theoretical interpretation continues to regard the brain as the primary organizing locus of the process, treating sensory signals as inputs for internal computations that subsequently generate motor corrections (Wolpert, Doya, & Kawato, 2003; Shadmehr & Wise, 2005). Within this framework, external mechanical structure itself is not regarded as the primary source of behavioral organization, but as information that must first be internally processed, represented, predicted, or inferentially reconstructed before adequate behavior becomes possible.

Within the GM, this organization is fundamentally reversed. The decisive structure that organizes haptic behavior arises not primarily within the brain, but within the externally specified mechanical dynamics that unfold during the continuous interaction between organism and environment. External mechanical properties already impose direct constraints upon possible movement trajectories as these manifest themselves on the sensory interface. Haptic perception therefore does not involve the internal reconstruction of a hidden mechanical reality, but the continuous stabilization of ongoing interaction with externally unfolding mechanical structure.

2. Externally Specified Mechanical Structure as Direct Behavioral Organization

Within dominant representational approaches, it is generally assumed that the organism must first construct internal representations or estimates of object properties before adequate behavioral regulation becomes possible. Haptic feedback processes, however, demonstrate that external mechanical structure already imposes direct constraints upon possible movement trajectories from the very first moment of contact. The environment therefore does not appear as a collection of neutral tactile stimuli that must first acquire meaning through internal processing, but as an immediately action-relevant mechanical reality within which certain movements are continuously enabled, constrained, or rendered impossible.

When an individual attempts to lift a heavy object, the external mass immediately reorganizes the muscular load, postural stabilization, joint pressure, movement velocity, and force regulation that support the further unfolding of the action. These changes do not first need to be internally "understood" or represented before corrections occur. The mechanical properties of the object directly influence the ongoing perception–action coupling itself. The same principle applies to slippery surfaces, elastic materials, unstable objects, or deformable structures. As soon as an object begins to slip or becomes mechanically unstable, the external dynamics immediately reorganize the further regulation of grip force, muscular activity, and movement coordination.

Within this continuous interaction, the organism therefore does not respond primarily to abstract representations of an external world, but to directly present mechanical structure as it manifests itself through continuous feedback on the sensory interface. Particularly during object manipulation, it becomes apparent that behavior does not unfold through a series of discrete internal decisions, but through continuous reciprocal modulation between external mechanical dynamics and organismic regulation. During object transport, musical performance, or the manipulation of fragile materials, extremely small corrections continuously occur that remain directly coupled to ongoing changes in resistance, pressure distribution, stability, and movement dynamics.

External mechanical structure therefore already specifies, to a large extent, which actions become possible, impossible, or necessary. Haptic feedback processes thus demonstrate particularly clearly that behavioral organization does not need to be primarily constructed internally. The environment already possesses intrinsic action structure as this structure manifests itself on the sensory interface during continuous organism–environment interaction, while neural dynamics continuously stabilize and modulate this externally unfolding mechanical coupling.

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3. Continuous Force Regulation and Dynamic Stabilization

The continuous regulation of grip force constitutes one of the clearest demonstrations of the externally specified organization of behavior. Within dominant inferential models, such regulation is typically explained in terms of internal predictions or representations of object properties, whereby the brain is assumed to continuously simulate future sensory states in order to correct movements appropriately. Haptic feedback processes, however, demonstrate that the necessary action structure is already present within the ongoing mechanical interaction itself.

When an individual holds a plastic cup, for example, stable behavioral regulation does not arise because the brain first calculates exactly how much force is required to prevent deformation. Minute changes in grip force immediately alter the mechanical state of the object, while these changes are directly projected back onto the sensory system and reorganize subsequent motor corrections. As soon as the cup begins to deform slightly or slip, the pressure distribution, muscular activity, joint stabilization, and movement dynamics that support the ongoing action change immediately. Stability therefore

does not arise from discrete internal computations about future states, but from continuous reciprocal modulation within the coupled organism–environment interaction itself.

The same principle becomes visible during precision actions such as writing, surgical manipulation, musical performance, or the handling of fragile materials. During such actions, extremely small corrections continuously occur, often within only a few tens of milliseconds. These corrections do not result from discrete conscious decisions or explicit internal reconstructions of object properties, but from the continuous mechanical reorganization of the interaction itself. Every minimal change in resistance, friction, deformation, or stability immediately alters the subsequent sensorimotor dynamics.

Within this continuous feedback structure, behavioral stability therefore does not exist as a preconstructed internal plan that is subsequently applied to the external world. Stability instead emerges as a dynamic property of the ongoing coupling between external mechanical structure and organismic regulation. The action remains coherent because external mechanical dynamics and neural stabilization processes continuously modulate one another.

It is precisely within continuous force regulation that it becomes apparent that the environment does not merely provide passive input for internal processing, but already actively participates in the organization of behavior. External mechanical properties continuously determine which forces are possible, which corrections become necessary, and which movement trajectories remain stable. The nervous system therefore functions not primarily as an internal reconstruction system of the world, but as a dynamic stabilization system that maintains coherent coupling to externally specified mechanical structure.

Conclusion

Haptic feedback processes demonstrate that the organization of behavior does not primarily arise from internal reconstructions of the world, but from direct coupling to externally specified mechanical structure as this structure manifests itself on the sensory interface. Within the GM, neural dynamics function as a stabilizing and modulating system that maintains the coherence of this coupling. Haptic feedback therefore provides a direct empirical illustration of the central proposition of the GM: the primary organization of behavior does not reside in the brain, but in the externally specified structure as it unfolds onto the sensory surface.

Chapter 5

The Externally Specified Structure onto the Sensory Interface - The External Structure in Visual Perception

Introduction

The first three chapters have explicated the mechanistic principles underlying the operation of the Gramophone Model (GM). They have argued that the sensory interface, rather than the brain, constitutes the primary organizing locus of perception, action, cognition, consciousness, and the memory and anticipatory processes that emerge from them. The central hypothesis of the GM is that the structure organizing behavior does not need to be internally constructed but is already present within externally specified dynamics as these are projected onto the sensory surface. The scientific value of this hypothesis ultimately depends on whether this projected structure is indeed capable of autonomously and successfully guiding behavior.

Visual perception constitutes one of the most fundamental domains in which this hypothesis can be examined. This chapter clarifies how this externally specified structure manifests itself within visual perception and how it already contains sufficient organization to guide perception and action without requiring an internal reconstruction of the world. To this end, the externally specified structure within visual perception is presented in four complementary categories: (1) the movement of environmental objects, (2) the zero-movement of environmental objects, (3) the egocentric movement of body parts, and (4) the egocentric movement of the body as a whole.

Although the present chapter analyzes a specific perceptual modality separately, this separation is purely analytical and does not reflect the organization of natural perception itself. Organisms are never confronted with isolated visual, auditory, proprioceptive, haptic, vestibular, olfactory, or other sensory inputs. At every moment, a single continuously changing hybrid sensory configuration is projected onto the entire sensory interface. These sensory dynamics never occur independently, but always emerge as mutually embedded aspects of one externally specified organism–environment relation. The present chapter isolates one modality solely for explanatory purposes, while recognizing that all perceptual organization ultimately unfolds within this continuously integrated sensory configuration.

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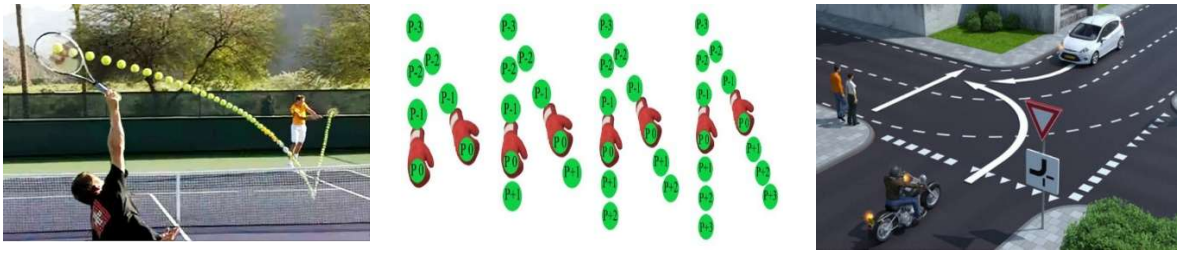
1. The Externally Specified Structure Underlying the Visual Perception of Moving Environmental Objects

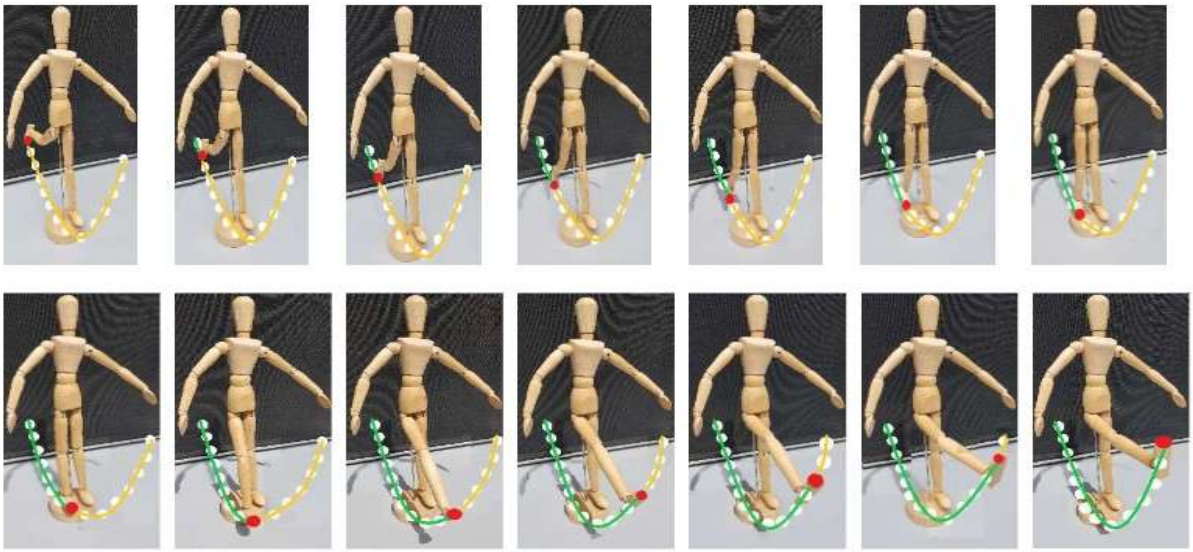
Within the explanatory model of the motoric movement action, visual perception consists of a continuous comparison process of successive adjacent time units. Each current projection onto the sensory surface is necessarily related to preceding and subsequent projections, allowing change, continuity, and movement to be perceived directly. Movement therefore does not appear as a property of isolated stimuli, but as a relational phenomenon emerging from the comparison of successive perceptual moments.

From this perspective, it also becomes clear that all perceived movement is relative. An approaching bicycle, for example, is perceived as an actual moving object, yet this difference disappears as soon as we ourselves begin cycling. In that case, the bicycle is perceived as a zero-movement. The externally specified structure underlying the perception of environmental objects can therefore be divided into two fundamental manifestations: movement and zero-movement. The present section focuses on actual movement.



Illustrations: *All movements of a tennis racket, a tennis ball, a boxing glove, or road users are embedded within lines. A moving object cannot simultaneously constitute a collection of completely independent positions. The position of the same object at successive times t(1), t(2), t(3), t(4), etc., always encompasses one and the same object moving through space. Precisely because these successive positions necessarily belong to the same object, they are inherently connected. Consequently, the movement does not manifest itself as a collection of isolated points, but as a single continuous action trajectory shape in which every current position is necessarily related to preceding and subsequent positions. The action trajectory shape therefore does not constitute a theoretical addition to movement, but the direct manifestation of the fact that one and the same object successively occupies different positions in space.*

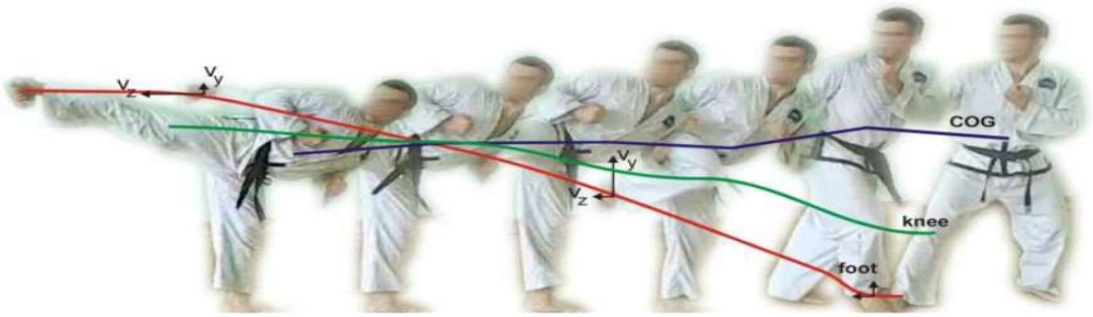
The explanatory model of the motoric movement action has demonstrated across a wide range of motor activities that perception necessarily organizes successive adjacent time units into action trajectory shapes[5]. This becomes visible in a broad variety of behaviors, including grasping, writing, eating, opening a lock with a key, sporting actions such as tennis and combat sports, and behavior in traffic. The same principle is particularly evident in everyday computer use, especially in the computer game Pong, as well as in auditory processes.



Across all of these examples, it becomes evident that successive positions of an external environmental object cannot exist independently of one another but must necessarily emerge as connected ele-

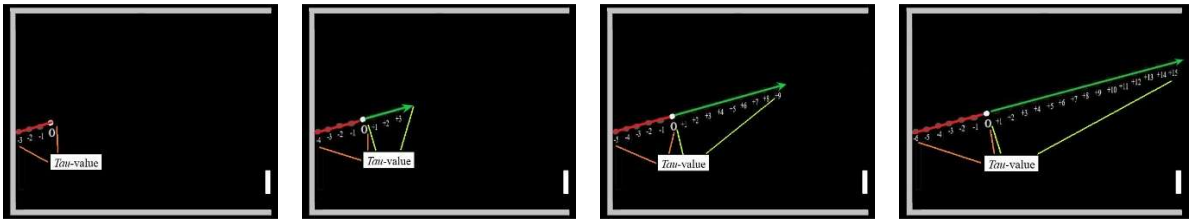
[5] https://www.researchgate.net/profile/Nj-Mol/research

ments within a single continuous action trajectory shape. Every environmental object is therefore inevitably organized within such a line structure. This implies that all manifest positions—for example, those of a foot during a combat action—together constitute a single action trajectory, in which the current position of the foot always forms the leading edge of the manifest segment, while the latent segment necessarily extends from the trajectory that has already been realized. Perception is thereby structured in such a way that, on the basis of previously acquired knowledge of movement forms, the global future course of the action trajectory can already be specified at an early stage of the unfolding action.



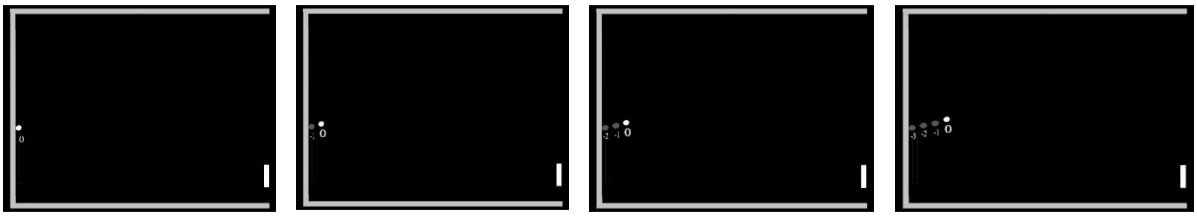
In this way, a global action trajectory shape can already be perceived at an early stage of the action on the basis of the manifest positions of the foot. The current position P(0) of the foot continuously forms the precise boundary between the manifest and latent segments of the trajectory, analogous to a marble in a marble run, where the current position already carries the further course of the track. Only by situating the movement of the foot within this complete line structure does it become possible to understand the development of the *tau*-value, which is based on the perception of the progressively diminishing distance within the latent segment of the action trajectory shape. At the same time, this organization makes visible how cortical processes necessarily mediate the deviations that arise within this continuous marble-run process.

Against this background, it becomes clear that the game Pong provides a particularly suitable context for explaining the externally specified structure underlying the visual perception of moving environmental objects. Within this highly constrained task, the formation and continuation of action trajectory shapes can be observed directly and in a controllable manner.



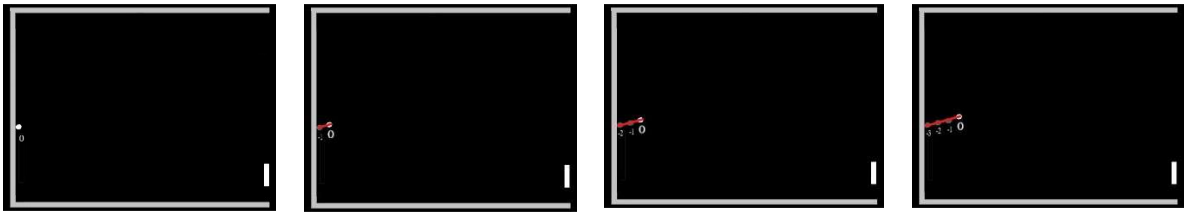
Pong: The perception of the pong ball illustrates the fundamental catch process that is present in every conceivable motor action. As soon as a limited number of successive manifest positions have become available, perception already gives rise to an implicit action-relevant projection of the further course of the trajectory on the sensory surface. This projection does not arise from conscious computation or complete visual information, but emerges directly from the externally specified continuity of the movement itself.

At the initial appearance of the pong ball, no coherent structure is yet available. However, as soon as multiple successive positions become manifest, these positions become organized into a continuous line structure, giving rise to a perceptual image of an unfolding trajectory that extends beyond the immediately visible information. This projection is not exact in detail, but sufficiently precise to specify the global form of the action trajectory shape.



1 2 3 4

Crucially, this process rests on the fact that the successive positions belong to one and the same object moving through space. Because these positions necessarily belong to the same object, they cannot exist as independent events but must be organized within a continuous line structure. Within this structure, the current position always forms the leading edge of the manifest trajectory while simultaneously constituting the boundary between the manifest and latent segments of the action trajectory shape.



1 2 3 4

Within this framework, the early emergence of such a line structure allows for the simultaneous projection of the egocentric movement required to intercept the ball, such that prediction is not an internal reconstruction of future states, but the direct perceptual consequence of the externally specified continuity of the trajectory, while the temporal dimension of this process becomes explicitly accessible as the tau-value, expressing the progressive reduction of the gap within the latent segment of the trajectory until the moment of contact.

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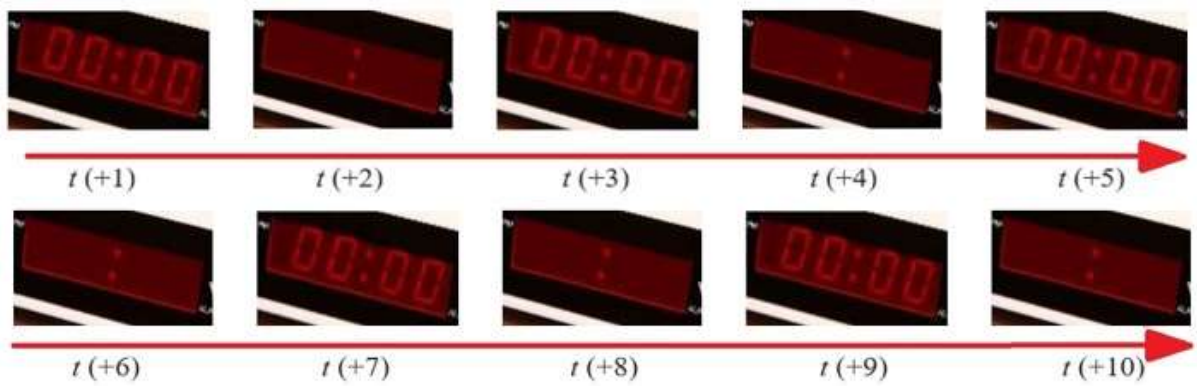
2. The Externally Specified Structure Underlying the Visual Perception of Stationary Environmental Objects

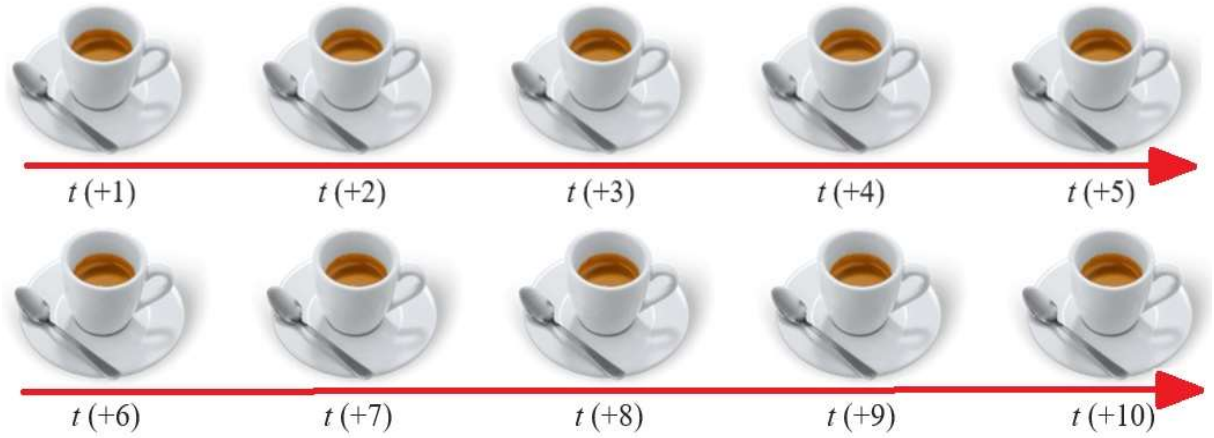
The explanatory model of the motoric movement action has likewise demonstrated how stationary environmental objects are perceived[6]. Contrary to conventional assumptions, stillness does not constitute a separate perceptual domain but is perceived within the same fundamental dynamics as movement. There is therefore no principled difference between the perception of a stationary object and that of a moving object.



[6] https://www.researchgate.net/publication/382069132_Einstein_the_Stationary_Coffee_Cup_and_the_Digital_Clock_The_Visual_Perception_Observes_Stationary_Coffee_Cups_Moving_in_Time

Consider the example of a digital clock whose zeros flash following a power outage. Each successive appearance of the zeros occurs at exactly the same spatial location, while each observation remains temporally distinct from the previous one. The perception of these zeros therefore does not arise from a persistent visual state, but from the continuous comparison of successive observations that are related solely through their identical spatial position. What is perceived as stillness therefore represents a special case of the same externally specified organization that underlies movement—or, stated differently, the same externally specified organization under conditions in which temporal succession continues while spatial displacement remains absent.

The same principle applies to the perception of a stationary coffee cup. The cup is not perceived as a static entity, but as a sequence of successive observations at times t(0), t(+1), t(+2), etc.. These observations remain related through their invariant spatial configuration, and the absence of positional change across successive observations leads to the conclusion that the object is stationary, even though the underlying perceptual process remains fully active and structurally identical to that involved in perceiving movement.



The comparison of successive adjacent time units is therefore just as active as in the perception of actual movement. The difference is simply that no positional change of the environmental object is detected. The object consequently occupies a zero-movement trajectory, within which the *tau*-value remains structurally zero. Any goal-directed motor action, such as grasping a coffee cup, therefore necessarily requires the organism to develop an egocentric action trajectory shape that can be brought into convergence with this zero-movement trajectory.

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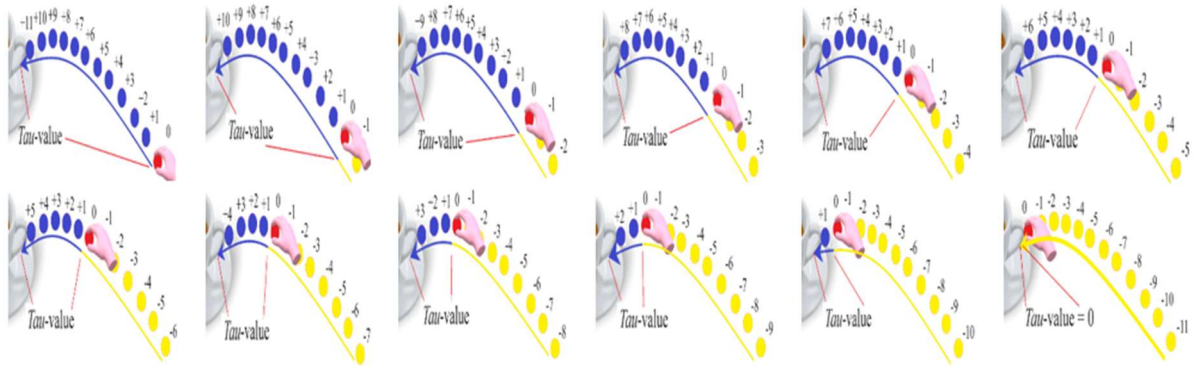
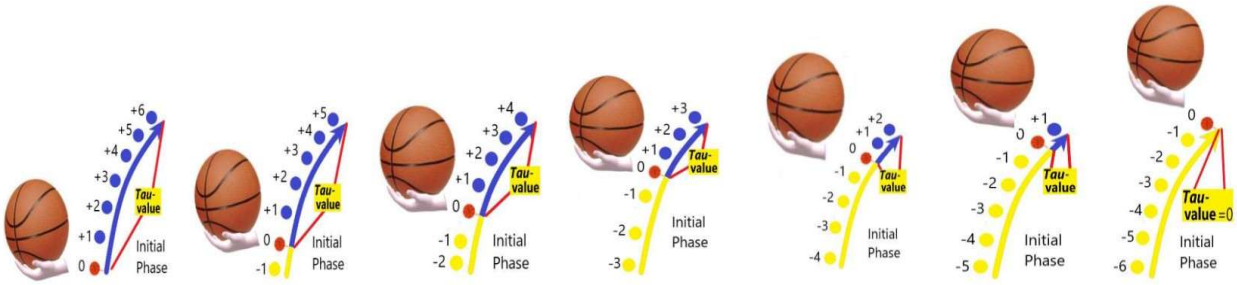
3. The Externally Specified Structure Underlying the Visual Perception of Egocentric Movement of Body Parts

Although Optic Flow is formally defined within Gibson's ecological framework as a relational phenomenon that arises directly from the movement of the organism, both the scientific literature and its dominant interpretation have become primarily focused on the movement structure of the environment. As a consequence, the egocentric component of this dynamic has remained conceptually underdeveloped, partly because motor actions are typically treated as a single undivided process.

Within the explanatory model of the motoric movement action, this omission is corrected by demonstrating that the egocentric movement of the organism cannot be understood as a derivative of environmental dynamics. Instead, it constitutes an autonomous action trajectory shape that develops in parallel with, and in necessary relation to, the action trajectory shape of the environmental object.

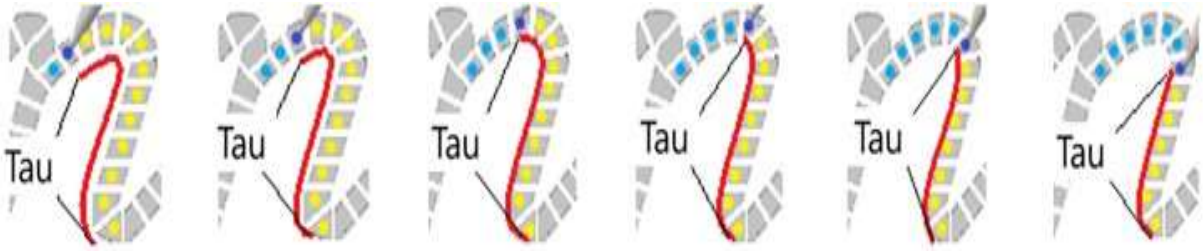


The externally specified structure underlying the perception of egocentric movement can be divided into two major categories: (1) the movement of body parts and (2) the movement of the body as a whole. The present section focuses on the first category, in which an arm, hand, or leg functions as the action object and can be visually perceived as a moving element within the visual field, analogous to a marble moving through a marble run.

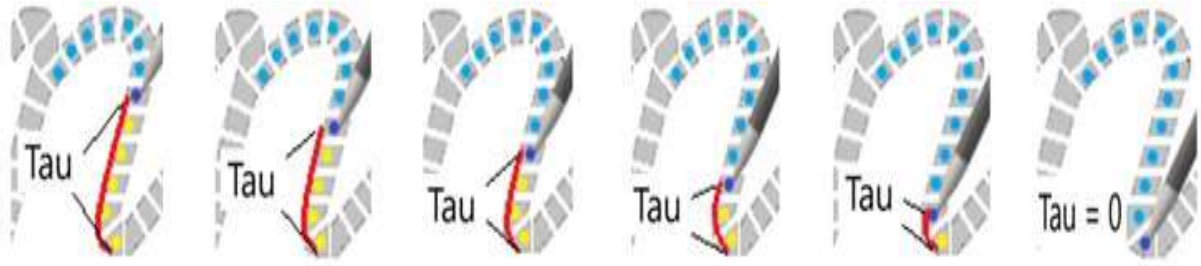


Illustrations: *Grasping a coffee cup, writing, or executing a basketball free throw demonstrates that egocentric movements are organized according to the same fundamental principle. In each case, the moving body part follows a continuous line structure in which every new position necessarily emerges from the preceding one. What is often described as predictive coding does not constitute a separate process but reflects the perception of this continuously unfolding movement itself. Perception and movement therefore do not operate as independent processes, but as different aspects of one and the same continuously developing action trajectory shape.*

This egocentric movement does not constitute a derivative of environmental dynamics, but an autonomous phenomenon in which successive positions of the action object necessarily emerge from one another and become organized into a continuous action trajectory shape according to the same structural principles that govern environmental objects. The explanatory model of the motoric movement action has demonstrated this across a wide range of motor activities, including grasping, posting a letter, opening a lock with a key, eating, writing, tennis serves, basketball free throws, golf swings, and more specialized tasks such as the nerve spiral game[7].



[7] https://www.researchgate.net/profile/Nj-Mol/research



Illustrations: *Also within writing, the actual position of the pen tip always forms the precise boundary between the manifest and latent segments of the action trajectory shape. A characteristic difference compared to many motor actions is the fact that the manifest segment of the action trajectory shape remains visible during writing.*

Within this dynamic, the same structural principles remain operative. The current position of the action object always occupies the leading edge of the manifest segment, the latent segment necessarily develops from the manifest segment, and the current position P(0) forms the precise boundary between the two. The development of the action trajectory shape is characterized by the *tau*-value as the temporal expression of the progressively diminishing distance within the latent segment. Only by understanding the movement as a whole—as a marble moving through a marble run—does it become possible to understand how cortical processes mediate deviations within this externally specified structure[8].

From this perspective, what is commonly described as predictive coding and what is described within ecological approaches as Optic Flow do not constitute separate processes. Both refer to different aspects of the same continuously unfolding perception–action dynamic, in which the organism remains continuously coupled to an externally specified action trajectory shape while cortical processes mediate the deviations that arise during its ongoing realization.

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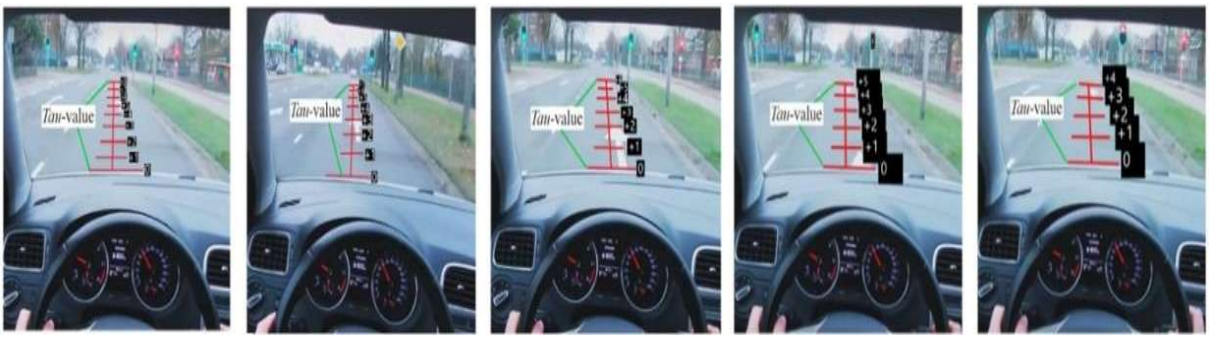
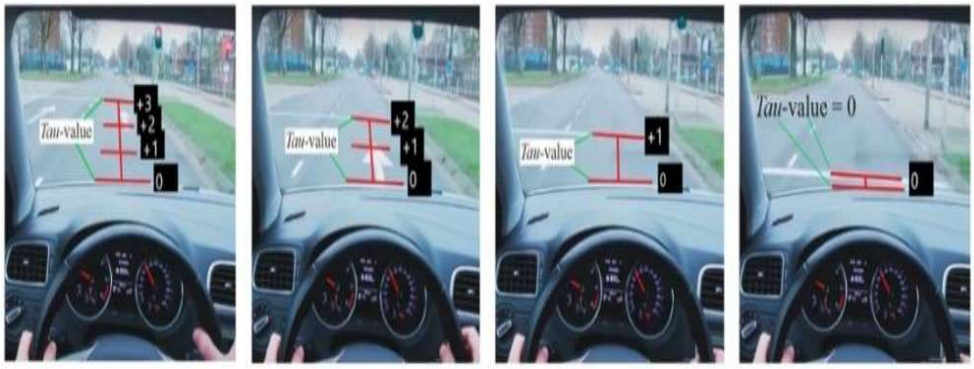
4. The Externally Specified Structure Underlying the Visual Perception of Egocentric Movement of the Body as a Whole

The perception of egocentric movement may be directed toward the movement of individual body parts, but also toward the movement of the body as a whole. During walking, cycling, rowing, or driving, the whole organism itself participates in the movement. In such situations, the movement can no longer be visually perceived as an external moving object, because the entire body executes the motor action and thereby constitutes the reference point from which the dynamics unfold.

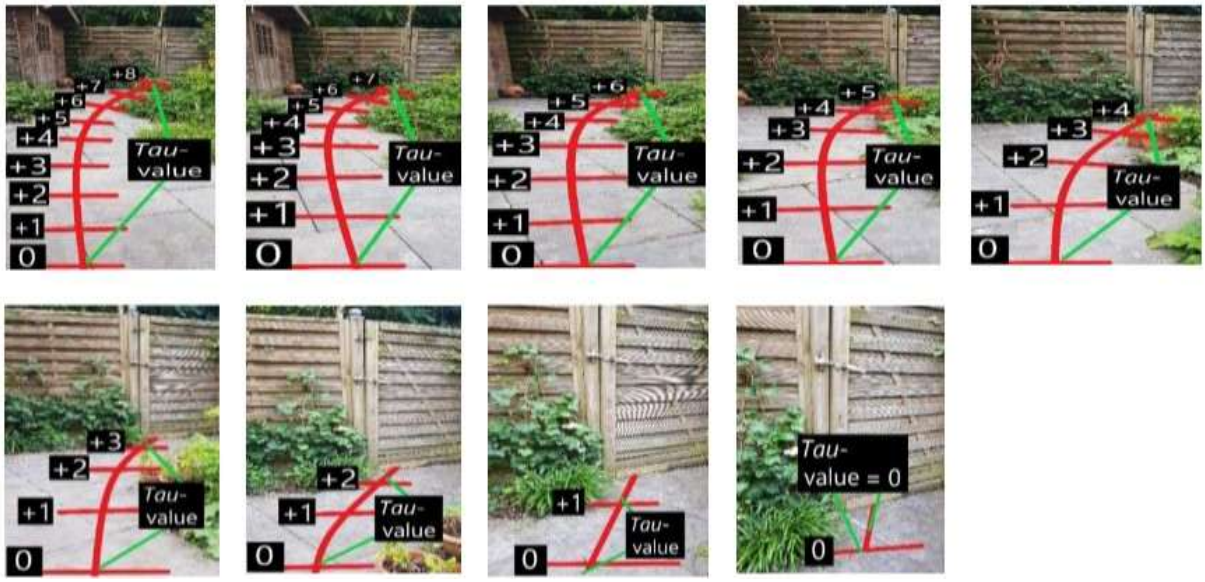


[8] https://www.researchgate.net/publication/382325018_The_complete_clarification_of_all_functional_perception_processes_within_writing?_sg%5B0%5D=ZJlqPe4RqhCz2hW6J5FWHRnu209TW6C8vIT3lnF-beNyVAYafIwPA6bGflWVKZ0T81OOmxJRbnJHgRCmOoLJAH7G4bdhuH2qKCilYXOwm.wH

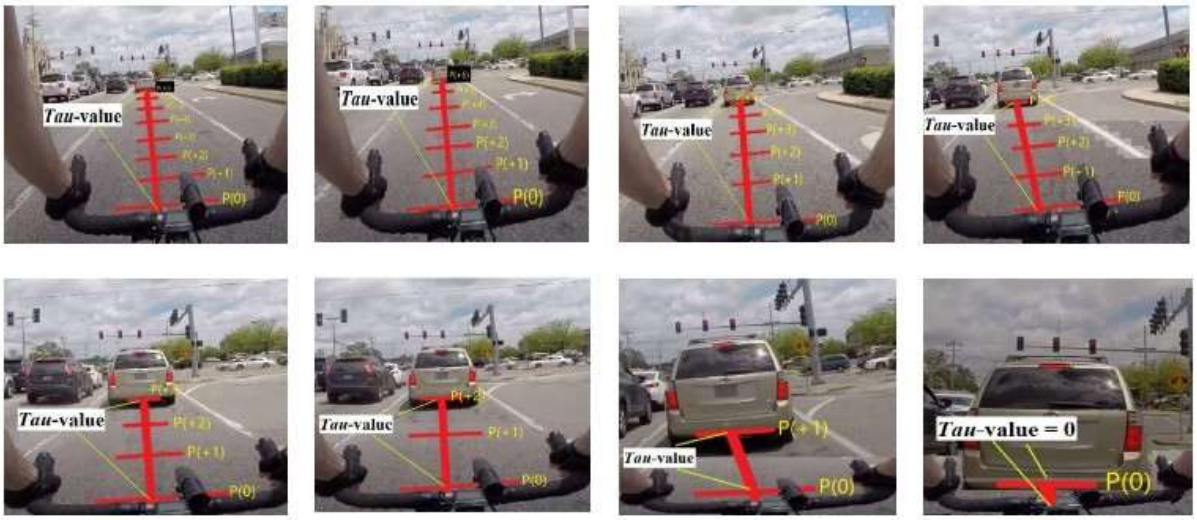


Perception can therefore no longer be directed toward an externally moving object, but exclusively toward one's own progression within the line structure, whereby the organism itself continuously forms the current position P(0) from which the movement develops, and the dynamics are experienced as the continuous reduction of the distance to a target. In this sense, perception here does not concern the observation of movement, but the direct experience of approaching the point of convergence within the external dynamics.

We can perceive a bobsled moving through a bobsled track, a walker moving along a path, or a long jumper during the run-up to the take-off board as environmental objects. However, we can also perform these actions ourselves, in which case the perspective reverses. Instead of perceiving an object moving along a trajectory, perception coincides with one's own progression along the action trajectory shape. This is more difficult to visualize because, in such cases, we are not observing the marble moving through the marble run—we become the marble itself.



Illustrations: *The animations of driving a car, walking toward a garden gate, and cycling toward a stationary car at a traffic light demonstrate that, when the organism as a whole is moving, a fundamental shift in perspective occurs. Perception shifts from following an externally moving object to experiencing one's own progression within the action trajectory shape. In all three cases, the organism itself forms the current position P(0), while the trajectory extends toward the relevant object, and the dynamics are experienced as the continuous reduction of the distance to the point of convergence—not as external movement, but as internal progression within the external structure.*



The same structural principles remain operative here. Successive positions are necessarily connected, the current position continuously forms the leading edge of the manifest segment, the latent segment necessarily develops from the manifest segment, and the *tau*-value expresses the temporal structure of the approaching point of convergence. This becomes evident, for example, when approaching a traffic light or reaching a target, where successful motor regulation can only be achieved when the egocentric action trajectory shape is brought into alignment with the action trajectory shape of the environmental object.

Conclusion

The analysis of visual perception demonstrates that the organization of behavior does not arise from the internal reconstruction of a heterogeneous stimulus field but emerges directly from the externally specified spatiotemporal structure as it manifests itself on the sensory surface. Within the explanatory model of the motoric movement action, perception consists of a continuous comparison process of successive adjacent time units, whereby successive positions of both environmental objects and egocentric movements do not appear as isolated stimuli, but as necessarily connected action trajectory shapes.

The transition from point representation to action trajectory shape constitutes the decisive turning point within this framework. Once successive positions are recognized as being necessarily connected, a direct organizing principle emerges that is capable of supporting the further unfolding of perception and action without requiring internal reconstruction, inference, or predictive modelling. Behavior therefore unfolds not from internally constructed representations of future states, but through continuous coupling to externally unfolding action trajectory shapes.

Within this dynamic, environmental objects and egocentric movements manifest themselves as two autonomous yet necessarily converging action trajectory shapes, whose future point of convergence constitutes the prerequisite for successful motor regulation. It thereby becomes evident that it is not the brain, but the externally specified dynamics themselves—as they manifest on the visual surface—that primarily specify the organization of behavior, while neural processes stabilize and mediate the organism's continuous coupling to this dynamic.

Chapter 6

The Externally Specified Structure onto the Sensory Interface – The External Structure in Auditory Perception

Introduction

The first three chapters have explicated the mechanistic principles underlying the operation of the Gramophone Model (GM). They have argued that the sensory interface, rather than the brain, constitutes the primary organizing locus of perception, action, cognition, consciousness, and the memory and anticipatory processes that emerge from them. The central hypothesis of the GM is that the structure organizing behavior does not need to be internally constructed but is already present within externally specified dynamics as these are projected onto the sensory surface. The scientific value of this hypothesis ultimately depends on whether this projected structure is indeed capable of autonomously and successfully guiding behavior.

Auditory perception provides a particularly suitable domain in which this hypothesis can be examined. Auditory events unfold as continuous temporal structures in which successive states necessarily emerge from preceding states while simultaneously constraining future developments. Sounds, words, rhythms, melodies, and conversations therefore do not appear as isolated events, but as continuously unfolding temporal dynamics whose organization already exists within the external world itself.

This chapter examines how this externally specified structure manifests itself within auditory perception and how it already contains sufficient organization to guide perception and action without requiring an internal reconstruction of auditory reality. It will be argued that auditory perception does not primarily arise from the internal reconstruction of discrete sound fragments, but from direct coupling to externally specified auditory dynamics as these are projected onto the auditory sensory interface. What within inferential approaches is typically attributed to internal prediction, reconstruction, and anticipatory processing will instead be shown to emerge directly from the continuous temporal organization of the auditory event itself.

Although the present chapter analyzes a specific perceptual modality separately, this separation is purely analytical and does not reflect the organization of natural perception itself. Organisms are never confronted with isolated visual, auditory, proprioceptive, haptic, vestibular, olfactory, or other sensory inputs. At every moment, a single continuously changing hybrid sensory configuration is projected onto the entire sensory interface. These sensory dynamics never occur independently but always emerge as mutually embedded aspects of one externally specified organism–environment relation. The present chapter isolates one modality solely for explanatory purposes, while recognizing that all perceptual organization ultimately unfolds within this continuously integrated sensory configuration.

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1. Auditory Perception in Contemporary Neuroscience: The Dominant Inferential Interpretation

Within contemporary neuroscience, auditory perception is generally understood as a hierarchical processing system in which the brain decodes successive auditory elements and internally organizes

them into coherent representations of words, rhythms, melodies, and sentences. Spoken language is often described as a particularly inferential problem because auditory input unfolds rapidly, is partially ambiguous, and is assumed to require continuous completion through contextual prediction (Friston, 2005; Clark, 2013).

Within predictive-coding frameworks, the auditory system is assumed to continuously generate predictions concerning upcoming sounds, phonemes, words, and sentence structures, while discrepancies between predicted and actual auditory input appear as prediction errors that are used to update internal models. Auditory perception is thereby primarily organized through internal inferential processes that probabilistically reconstruct future auditory states.

Within this framework, however, the external auditory dynamics itself remains remarkably underspecified. Auditory events are typically treated as successive input fragments that must be internally integrated into coherent perceptual structures, whereas the intrinsic temporal organization of the auditory event itself is rarely considered as the primary organizing principle of perception and action.

Auditory perception, however, makes particularly clear that successive auditory states cannot exist independently of one another. Words, rhythms, melodies, and conversations necessarily unfold as continuous temporal line structures in which each actual auditory state emerges from preceding states while simultaneously constraining future developments. The auditory world therefore does not appear as a collection of isolated stimuli, but as a continuously unfolding externally specified temporal dynamic.

Within the GM, auditory perception is therefore not understood as the internal reconstruction of auditory input, but as continuous coupling to an already externally organized auditory action trajectory shape. What within inferential frameworks appears as prediction, internal anticipation, or the reconstruction of future auditory states emerges within the GM directly from the temporal continuity of the auditory structure itself as it is projected onto the auditory sensory interface.

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2. Auditory Perception within the Gramophone Model: The Externally Specified Temporal Structure of Auditory Events

As established in Chapters 1–3, the continuous arrival of externally specified stimuli at the sensory interface necessarily gives rise to temporally organized structures. Because successive temporal units are never identical, yet remain structurally coupled through their continuous unfolding, each actual sensory state emerges from preceding states while simultaneously constraining future developments. Auditory perception makes this principle particularly explicit. Successive auditory stimuli continuously arrive at the auditory sensory interface in adjacent temporal units, thereby generating a continuously unfolding temporal organization that cannot appear as a collection of isolated sounds but necessarily emerges as a coherent auditory structure extending across time.

Auditory events therefore always appear as temporal action trajectory shapes. Every sound necessarily exists within an unfolding auditory line structure in which successive auditory states emerge from preceding states while simultaneously constraining future developments. Just as within visual trajectory structures, auditory states cannot appear arbitrarily or independently of one another but must necessarily arise from preceding temporal segments and remain coupled to the further unfolding of the auditory event. The resulting auditory organization therefore does not consist of isolated sounds, words, or rhythms, but of a continuously unfolding auditory action trajectory shape extending across successive moments in time.

This principle becomes immediately visible in simple auditory sequences. When someone utters: 1, 2, 3, 4, a perceptual image of the further auditory structure already emerges after only a few auditory po-

sitions. The listener almost immediately responds with: 5, 6, 7, 8, not because the individual numbers are internally calculated, but because the auditory action trajectory shape, as projected on the auditory sense, itself already specifies the further unfolding of the sequence.

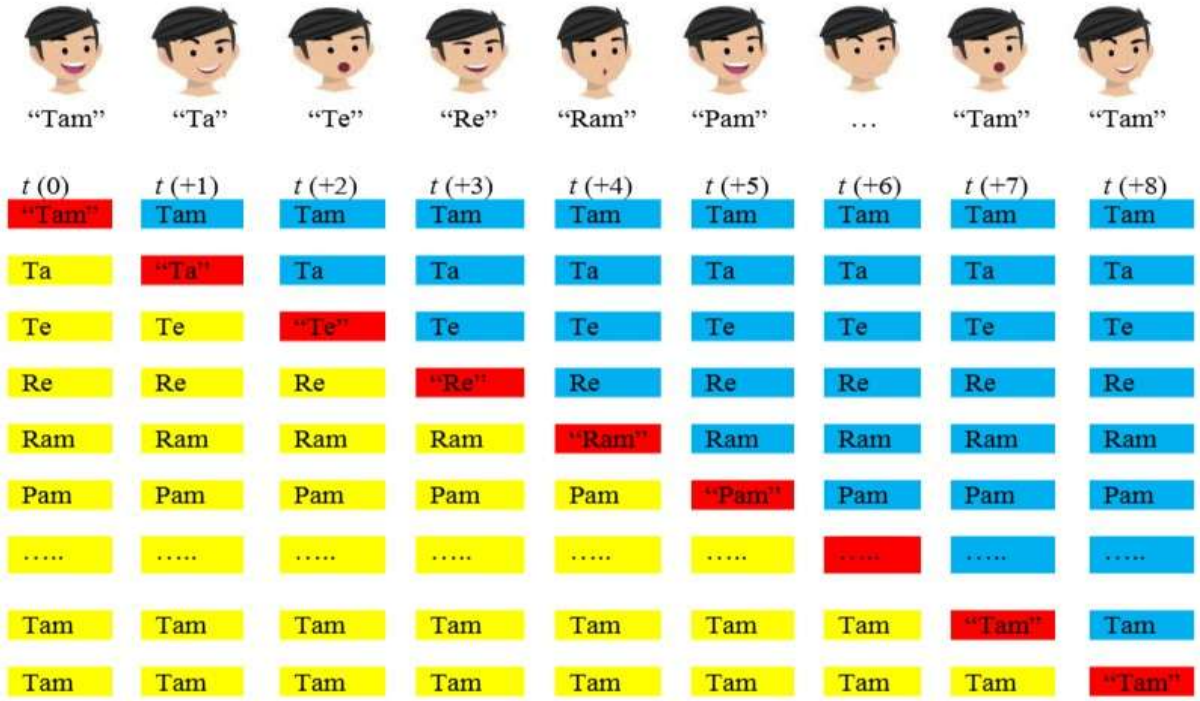


Illustration: *In a familiar chant*[9]*, only a few words are often sufficient for listeners to form a perceptual image of the entire auditory action trajectory shape, that is, of the complete marble-track structure still to be traversed. Within the GM, this implies that residual traces of previous auditory experiences are continuously fed back across the already manifest auditory structure. Only through this feedback process does the actual position P(0) of the currently uttered segment acquire meaning, continuously marking the boundary between the manifest and the still latent segments of the auditory action trajectory shape. As the auditory marble-track structure progressively closes through the unfolding words, the tau-value approaches zero in exactly the same manner as observed in any goal-directed motor action.*

The numerical example merely serves as a simplified illustration of a more general principle. The same organization applies to letters, syllables, words, sentences, rhythmic patterns, melodies, chants, and conversations. In all cases, successive auditory states derive their significance not in isolation, but from their position within a larger unfolding auditory action trajectory shape.

The same principle remains present when the temporal structure changes. When someone utters: 1...2...3...4, the listener responds: 5...6...7...8. Likewise, when the sequence unfolds as 1.....2.....3.....4, the response becomes: 5.....6.....7.....8. Not only the numerical sequence, but also the interval structure is directly perceived as part of one continuous auditory action trajectory shape. Pauses therefore do not function as an absence of structure, but as an integral component of the temporal organization of the auditory dynamics. The listener does not merely perceive the individual numbers, but the entire unfolding auditory structure, including its temporal rhythm and interval organization.

Within this continuously unfolding structure, every actual auditory state constitutes the actual position P(0) of the auditory action trajectory shape. This actual auditory position simultaneously marks the

[9] https://www.researchgate.net/publication/355097175_The_complete_and_final_clarification_of_catching_-_All_motoric_actions_encompass_interceptive_tasks_-_The_catching_of_soundswords

boundary between the manifest and latent segments of the auditory structure. From the already manifest segment, a perceptual image therefore emerges of the further latent unfolding of the auditory action trajectory shape.

This becomes particularly evident within familiar auditory action trajectory shapes. As soon as several manifest segments of a chant, rhythmic structure, or auditory sequence have unfolded, a global perceptual image of the further auditory unfolding already emerges. Listeners do not perceive future sounds as isolated predictions but instead couple themselves to an already externally unfolding auditory structure whose latent segment becomes progressively more specified.

Within the GM, this continuity arises because residual structure from previous auditory experiences is continuously fed back across the already manifest auditory action trajectory shape, causing the actual auditory position P(0) to continuously acquire meaning as the boundary between the manifest and latent segments of the auditory dynamics.

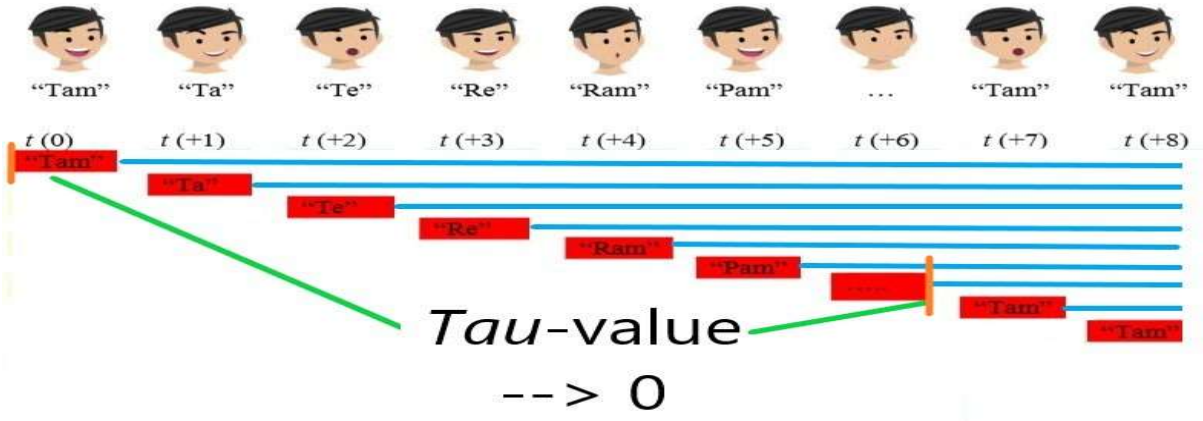


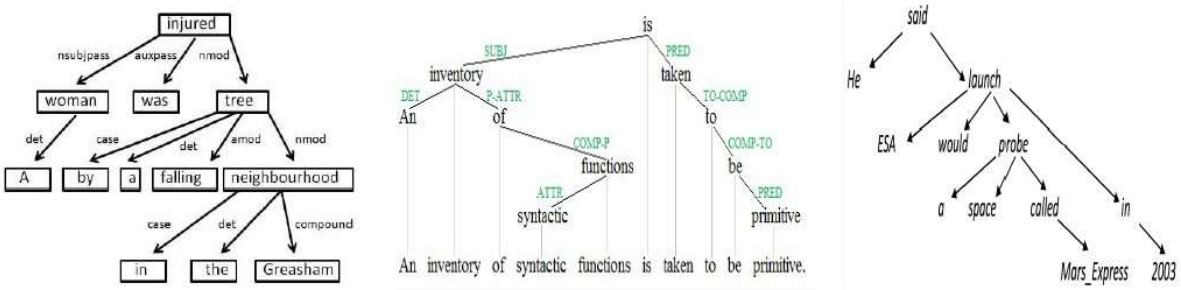
Illustration: *After only the third sound segment of a familiar chant, most listeners who are familiar with it already recognize which chant is unfolding. Based on the rhythm, which for the most part remains within similar fluctuation boundaries although never identically reproduced, they form a perceptual image of the entire marble-track structure, particularly of its latent segment. As the tau-value approaches zero upon reaching the chant sound "Pam", the listener switches to active speech in order to complete the perceptual image of the entire marble-track structure, as projected onto the sensory interface, that already exists.*

As the auditory action trajectory shape continues to unfold, the *tau*-value progressively approaches zero, analogous to convergence processes observed in motor interception actions. Once the auditory structure has become sufficiently specified, the listener can actively participate in the further auditory unfolding by completing the remaining segment of the auditory action trajectory shape. Auditory participation therefore does not arise from the separate internal reconstruction of future sounds, but from continuous coupling to an already externally unfolding temporal structure.

This mechanism becomes particularly evident in syntax and spoken language. As soon as several words have become manifest, a strongly constrained field of possible further developments already emerges. Within dominant predictive frameworks, this phenomenon is typically interpreted as the internal prediction of future words. Within the GM, however, this structure emerges directly from the externally unfolding auditory dynamics themselves. The actual auditory position continuously forms the boundary between the manifest and latent segments of the auditory action trajectory shape, while the further unfolding must necessarily emerge from what has already become auditorily realized.

Syntax dependency trees make this mechanism explicitly visible. Words do not appear as isolated auditory elements, but as temporally coupled positions within a single overarching auditory action trajectory shape. The dependency relations between words demonstrate that the latent segment of a sentence

must emerge from its manifest segment, while the actual auditory position continuously marks the precise boundary between the two. Syntax therefore provides a direct illustration of how auditory perception and auditory cognition remain coupled to an externally unfolding temporal structure rather than to independently generated internal predictions.



Illustrations: *Syntax dependency trees show that words are not selected randomly within conversations. Both sentence construction and the perception of spoken words are organized around established dependency relations and phrase structures that have become incorporated through previous experience. Syntax dependency trees strongly support the explanatory framework of the GM. They make explicit that the latent segment of a sentence must emerge from its manifest segment, that the actual word perceived at P(0) continuously marks the precise boundary between the manifest and latent sentence structure, and that the perceptual images of individual words form part of a single auditory action trajectory shape in which each occupies a unique and temporally specified position.*

Within the GM, auditory cognition therefore does not emerge from internal symbolic reconstruction, but from continuous coupling to externally unfolding auditory line structures that are already temporally organized within the external dynamics themselves as these are projected onto the auditory sensory interface. What within inferential approaches is commonly attributed to internal prediction, symbolic processing, or anticipatory reconstruction is instead understood as the direct consequence of continuous coupling to an externally specified temporal organization. Auditory cognition therefore remains fundamentally grounded in the unfolding structure of the auditory event itself rather than in internally generated representations of future auditory states.

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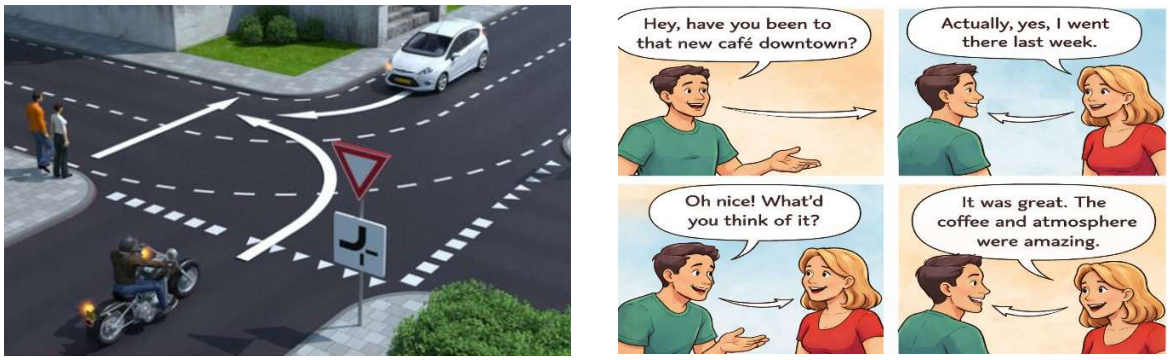
3. Auditory Flow: Continuous Coupling in Conversational Dynamics

Just as Gibson's Optic Flow emerges within visual perception through continuous movement in the external environment, a form of auditory flow emerges within auditory interaction. Conversations, verbal exchanges, and rhythmic interactions unfold as coupled auditory action trajectory shapes in which participants continuously coordinate their behavior relative to one another.



Illustrations: *In both conversations and traffic, the objective is not to construct an actual point of intersection with the action trajectory shapes of other participants. Instead, behavior is organized*

through the temporal or spatial openings that exist within those trajectory shapes. Within both language and traffic, organisms continuously make use of the available gaps within the unfolding action trajectory shapes of others. This gives rise, within auditory interaction, to a form of auditory flow that is structurally analogous to Optic Flow within visual perception. One participant speaks while another listens, after which the roles reverse. Auditory interaction therefore consists of a continuous alternation between environmentally generated auditory dynamics and egocentric auditory production, with participants continuously referring to, listening to, and coordinating with the unfolding sounds produced by others. In this respect, movement within conversational interaction is organized in the same manner as movement within traffic: in both cases, behavior is guided through the openings that exist within the action trajectory shapes of other participants rather than through direct convergence with those trajectory structures themselves.

During conversations, individuals do not respond to isolated words but continuously position themselves within the temporal openings of one another's auditory action trajectory shapes. Speakers and listeners together form a single continuously unfolding auditory dynamic in which turn-taking, pauses, intonation changes, and rhythmic transitions organize the further development of the interaction.

Within this dynamic, no actual physical interception point emerges as in motor interception actions. Instead, participants continuously utilize the temporal gaps within the auditory action trajectory shapes of others. As one speaker temporarily closes a segment of the auditory structure through intonation, rhythmic deceleration, or a temporal opening, another speaker can initiate the next segment of the unfolding interaction.

Auditory interaction therefore exhibits the same fundamental organizational principles as traffic dynamics and many forms of sport interaction. In all cases, behavior is organized through continuous attunement to externally unfolding trajectory structures within which organisms continuously position themselves relative to one another.

The same principle becomes visible within music and collective rhythmic interaction. Rhythmic structures function as continuous temporal action trajectory shapes with which participants continuously synchronize. Musical coordination therefore does not arise from the separate processing of isolated auditory stimuli, but from continuous coupling to an already externally unfolding auditory dynamic.

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4. Cortical Stabilization of Externally Specified Auditory Dynamics

Although auditory action trajectory shapes often provide an early global specification of the further temporal unfolding, the subsequent auditory development can never be fully predetermined. Every auditory event remains subject to fluctuations, deviations, and contextual variations. Within the GM, however, such deviations are not interpreted as errors in internal predictions, but as necessary fluctuations within a continuously unfolding external auditory dynamic[10].

Whenever an unexpected word occurs during conversation, a speaker suddenly changes rhythm, or a musical structure deviates from its anticipated course, cortical processes must immediately reorganize the global auditory perceptual image. This reorganization, however, does not involve the reconstruc-

[10] https://www.researchgate.net/publication/361184701_The_cortical_streams_mediate_the_auditory_perception_of_soundswords_in_the_exact_same_way_as_they_mediate_the_visual_perception_of_an_incoming_ball_trajectory_shape_-_The_zig-zag-process_and_the_harmo?_sg%5B0%5D=qa5phczsfxtnChHsU3c8sUno1yd-gGxR6lei295fXjYbXKLfxSVdb8ybKVIwJGpC03maO_Pyap97LRJwqj2osfcget-gIgMjwmSmQpIwZs.63Gc9UJJBRWi1IizT6pZaMALQQU_5BHEH8pgsy6g2OYMMWxk0STgPx0HlaPqyDnMslt5IMuYX5JxnsKDDAjqhg&_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InByb2ZpbGUiLCJwYWdlIjoicHJvZmlsZSIsInBvc2l0aW9uIjoicGFnZUNvbnRlbnQifX0

tion of an internal model of the world, but the continuous stabilization of coupling to the changing external auditory structure.

Prediction errors therefore acquire a fundamentally different meaning within auditory perception than within inferential predictive-coding frameworks. They do not refer to errors in internal representations of future auditory states, but to deviations between the global perceptual image of the auditory action trajectory shape and its actual further unfolding.

Just as visual perception requires the continuous mediation of deviations between the global perceptual image and the ongoing development of visual trajectory structures, auditory perception likewise requires the continuous mediation of temporal and structural deviations that must be integrated into the further auditory unfolding. The auditory system therefore does not function as an internal reconstruction mechanism of sound, but as a dynamic stabilization system that maintains coherent coupling to externally unfolding auditory structure as projected onto the auditory sensory interface.

Conclusion

The analysis of auditory perception demonstrates that auditory events do not appear as isolated sensory fragments requiring internal reconstruction, but as continuous externally specified temporal action trajectory shapes. Successive auditory states are necessarily coupled across time and continuously constrain the further unfolding of the auditory dynamics.

The actual auditory state continuously forms the boundary between the manifest and latent segments of the auditory action trajectory shape, thereby providing an early global specification of its further development. Auditory perception therefore does not primarily depend upon internal prediction or inferential reconstruction, but upon continuous coupling to an externally unfolding temporal structure.

Conversations, rhythmic interactions, music, and spoken language make particularly clear that organisms continuously position themselves within auditory action trajectory shapes that are already externally organized. The nervous system does not internally create this structure but continuously stabilizes and modulates coupling to it. Auditory perception, auditory cognition, and auditory participation thereby emerge as different manifestations of the same underlying process.

Auditory perception therefore demonstrates, just as visual and haptic perception, that the decisive organization of behavior does not primarily arise within the brain itself, but is already present within externally specified dynamics as these are projected onto the sensory interface. The brain does not construct the temporal organization of auditory reality but continuously stabilizes coupling to an externally unfolding auditory structure.

Chapter 7

The Externally Specified Structure at the Sensory Interface — The External Structure in Proprioceptive Perception

Introduction

The first three chapters have explicated the mechanistic principles underlying the operation of the Gramophone Model (GM). They have argued that the sensory interface, rather than the brain, constitutes the primary organizing locus of perception, action, cognition, consciousness, and the memory and anticipatory processes that emerge from them. The central hypothesis of the GM is that the structure organizing behavior does not need to be internally constructed but is already present within externally specified dynamics as these are projected onto the sensory surface. The scientific value of this hypothesis ultimately depends on whether this projected structure is indeed capable of autonomously and successfully guiding behavior.

Proprioceptive perception constitutes a particularly important domain in which this hypothesis can be examined. Within current neuroscientific accounts, proprioceptive signals are typically treated as afferent inputs that must be integrated into an internal body schema or internal model of the body. Such approaches assume that the spatial organization of bodily relations is ultimately constructed within the nervous system. Within the GM, this ordering is fundamentally reversed. Proprioceptive signals do not express an unstructured sensory input requiring internal organization, but a physically and relationally structured system of bodily dynamics.

Where visual perception is organized by externally specified action trajectory shapes of movement and zero-movement, and auditory perception by temporally unfolding auditory action trajectory shapes, proprioceptive perception concerns a third fundamental form of externally specified structure: the continuously changing relational organization of the body itself. Proprioceptive perception therefore does not primarily concern isolated sensations arising from muscles, tendons, or joints, but the lawful relations that continuously emerge between body parts during ongoing action.

The body consequently does not appear as a collection of independent segments, but as a continuously organized relational field in which successive bodily states necessarily emerge from preceding states and constrain the further development of action. Proprioceptive perception therefore concerns the perception of relational action trajectory shapes that unfold between body parts as they continuously change position, orientation, tension, and movement relative to one another.

The following sections show how this externally specified relational structure manifests itself, as projected onto the proprioceptive sensory interface, and how it already contains sufficient organization to guide proprioceptive perception and action without requiring the assumption of an internally constructed body model.

Although the present chapter analyzes a specific perceptual modality separately, this separation is purely analytical and does not reflect the organization of natural perception itself. Organisms are never confronted with isolated visual, auditory, proprioceptive, haptic, vestibular, olfactory, or other sensory inputs. At every moment, a single continuously changing hybrid sensory configuration is projected

onto the entire sensory interface. These sensory dynamics never occur independently but always emerge as mutually embedded aspects of one externally specified organism–environment relation. The present chapter isolates one modality solely for explanatory purposes, while recognizing that all perceptual organization ultimately unfolds within this continuously integrated sensory configuration.

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1. Proprioceptive Perception in Neuroscience: The Dominant Inferential Interpretation

Within current neuroscientific accounts, proprioceptive perception is typically described as a system that provides internal information about muscle length, joint angles, tension, and body position. These signals are assumed to be centrally integrated into an internal model of the body through which movements can be planned, controlled, and corrected. Concepts such as body schema, motor representations, sensorimotor integration, and internal models implicitly assume that the spatial organization of bodily relations is ultimately constructed and maintained within the nervous system.

Within such accounts, however, the question remains how the continuously changing relations between body parts are organized across ongoing action. Even relatively simple motor behaviors require the continuous coordination of multiple bodily segments whose mutual relations change moment by moment throughout the movement. Proprioceptive perception must therefore remain sensitive to a highly dynamic relational organization.

Within the GM, this problem is approached differently. Proprioceptive structure does not need to be internally constructed because it is already present within the relational dynamics of the body itself. Muscles, tendons, and joints do not merely provide isolated signals that subsequently acquire meaning through internal processing but continuously express the changing relations between body parts as these are projected onto the proprioceptive sensory interface.

Proprioceptive perception therefore does not concern the internal reconstruction of body position, but the continuous stabilization of externally specified relational action structures. The nervous system does not primarily create this organization itself, but continuously follows, stabilizes, and modulates the relational dynamics of the body as they unfold across time.

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2. The Unrecognized Phenomenon of Proprioceptive Perception

A fundamental difficulty in the analysis of proprioceptive perception is that this form of perception often possesses only limited direct phenomenological accessibility. Individuals generally understand proprioception conceptually yet frequently experience difficulty attending to it as a distinct perceptual domain. Whenever one attempts to introspectively imagine a movement, a visual image often emerges almost immediately, creating the impression that the underlying perception is primarily visual in nature.

Crucially, however, visual perception does not replace proprioceptive perception. When visual information is available, proprioceptive perception continues to operate autonomously alongside visual perception, giving rise to a hybrid perceptual constellation in which both modalities specify the same underlying action structure through different forms of sensory mediation.

Therefore, the autonomous nature of proprioceptive perception often remains unnoticed. This becomes particularly evident when visual information is absent. Individuals who are blind from birth are capable of performing complex motor actions, localizing body parts, and executing precise movement sequences without visual support. The underlying perception is therefore not derived from a visual domain but possesses its own spatial and relational organization.

Within representational accounts, it remains difficult to explain how such an organized relational system could arise without reference to visual experience. Within the GM, this problem does not emerge

because proprioceptive structure is not internally constructed but arises directly from the relational dynamics of the body itself as projected onto the proprioceptive sensory interface.

The apparent inaccessibility of proprioceptive perception therefore does not reflect an absence of structure, but rather the particular way this structure manifests itself. Proprioceptive perception does not typically appear as an explicit image or discrete perceptual content, but as a continuously unfolding relational field that functions primarily in the service of ongoing action.

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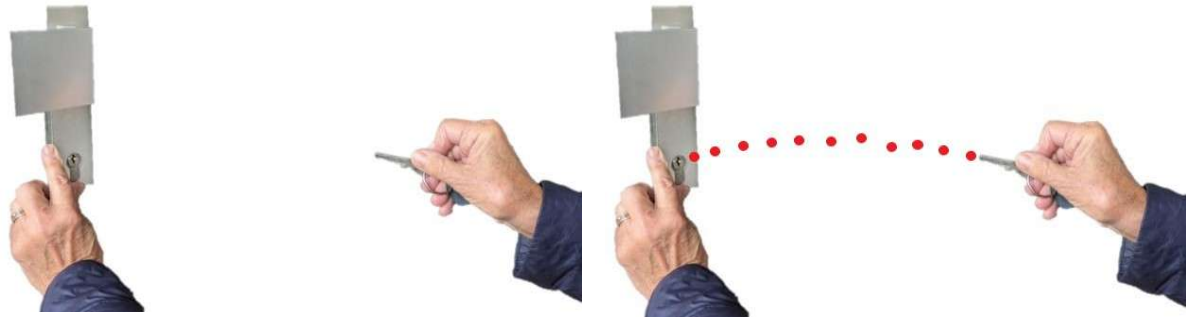
3. The Externally Specified Structure in Proprioceptive Perception within Motoric Actions Involving an Environmental Object

When attempting to open a door lock with a key in complete darkness, the lock is first localized with the non-key hand. Through this localization, a proprioceptively specified action trajectory shape is established between the key tip and the lock. The subsequent action can then be executed successfully without any visual support.



Illustrations[11]: *In total darkness, we place the non-key hand at the lock. The entire action is then carried out identically to the procedure in daylight. The novum here, however, is that the three obligatory foci are now perceived entirely proprioceptively: (1) the movement of the lock, which in this particular case consists of zero-movement, (2) the external movement of the key tip (primary egocentric focus), and (3) the internal bodily movements directed toward the key head (secondary egocentric focus).*

What becomes apparent in this situation is that proprioceptive perception is fully capable of carrying the action structure on its own. Even in the complete absence of visual information, the relation between hand, arm, key, and lock remains continuously available throughout the action. As the movement unfolds, these changing relations are followed and stabilized proprioceptively, allowing the key to be guided successfully toward the lock.

When the same action is performed under daylight conditions, the situation appears very different. The lock, the key, and the movement toward the lock can now be visually perceived throughout the action. As a result, it becomes easy to assume that visual perception has taken over the guidance of the movement and that proprioceptive perception has become less important or has disappeared altogether.

What actually changes, however, is not the presence of proprioceptive perception, but the addition of visual perception. The same action trajectory shape that was specified proprioceptively in darkness is now specified visually as well. Both perceptual domains remain autonomously present and together form a hybrid perceptual constellation in which the same underlying action structure is simultaneously mediated through multiple sensory modalities.

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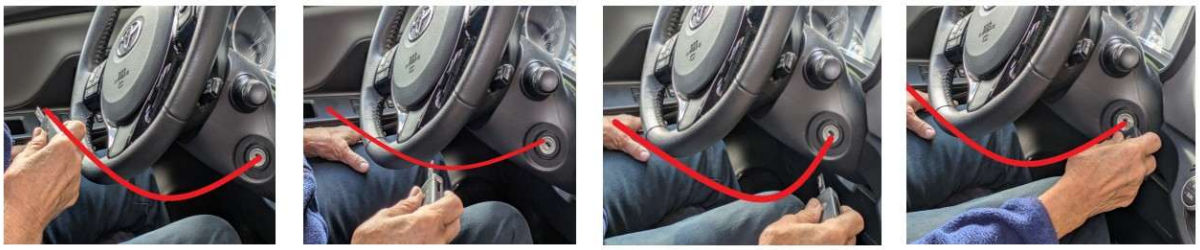
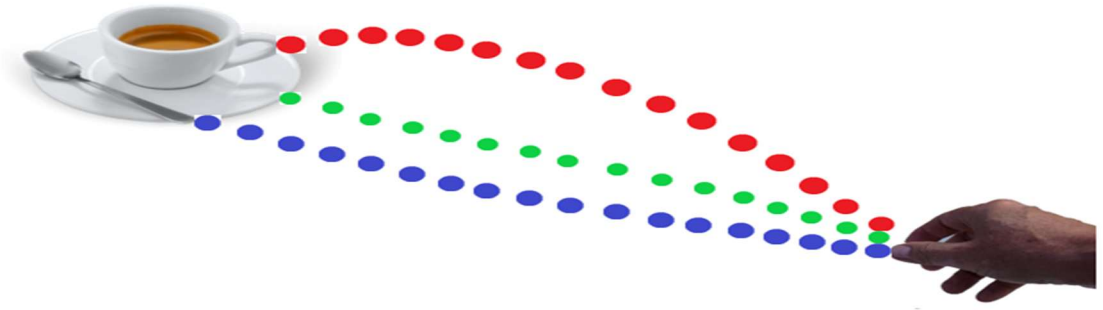
[11] All illustrations are necessarily presented as visual images and may therefore create the impression that proprioceptive perception is related to visual perception. This is not the case. The figures serve solely as explanatory aids. The underlying proprioceptive structures cannot themselves be directly seen and are therefore difficult to illustrate without visual representation.



Illustrations: *In an unfamiliar vehicle, the process of starting the car often begins with a visual search for the ignition slot. Through repeated execution the action trajectory shape becomes progressively stabilized through proprioceptive coupling, eventually allowing the movement to be executed with little or no visual guidance.*

The same principle appears throughout countless everyday actions. When we pick up a coffee cup, grasp a door handle, or operate a light switch, visual and proprioceptive perception continuously unfold together. So, when visual attention at moments shifts elsewhere, the movement can continue without difficulty because the underlying action structure always remains available proprioceptively.



It is precisely in such everyday situations that the autonomous nature of proprioceptive perception becomes visible. Proprioception does not merely supplement visual perception but provides direct access to the changing relations between body parts and action objects throughout the movement. Whenever the movement of an action object can be visually followed along an action trajectory shape, the same movement is simultaneously perceived proprioceptively. Seeing and feeling therefore do not appear as separate processes, but as concurrent manifestations of one and the same externally specified action structure as projected onto different sensory interfaces.

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4. The Externally Specified Structure in Proprioceptive Perception within Motoric Actions Involving the Body Itself

Within motoric actions involving the body itself, the externally specified structure does not first need to be projected onto the sensory interface through an environmental object. Instead, it manifests directly within the proprioceptive dynamics of the body. The relations between body parts are not perceived as isolated bodily sensations, but as continuously unfolding relational structures as projected onto the proprioceptive sensory interface.

As a consequence, latent action trajectory shapes continuously exist between body parts and can be immediately activated whenever they become functionally relevant. Proprioceptive perception therefore does not primarily concern individual sensations arising from muscles, tendons, or joints, but the ongoing perception of changing relations between bodily segments during action.

Successive proprioceptive states do not appear as separate signals. Rather, they emerge as continuously connected action trajectory shapes in which each actual position necessarily arises from preceding relational configurations and simultaneously constrains the further unfolding of the movement.

The body therefore appears as a continuously organized relational field in which perception and action remain directly coupled throughout the execution of the motor act.

Illustrations: *Within proprioceptive perception, the moment at which both hands are positioned on the head can be taken as a starting configuration from which action trajectory shapes can be constructed and executed simultaneously toward virtually any other body part. With practice, separate action trajectory shapes can even be performed at the same time, for example toward the shoulder and the knee, or in combinations such as belly–knee, ear–hip, and many others. Within this children's dance Head, Shoulders, Knees and Toes, however, the movements remain synchronous. What becomes apparent is that the two arms ultimately form two autonomous yet perfectly mirrored action trajectory shapes, revealing the highly organized relational structure that characterizes proprioceptive perception.*

The fact that action trajectory shapes can be realized entirely proprioceptively between body parts reveals that such relational structures exist throughout the body. Between all bodily segments, latent action trajectory shapes remain continuously available within the externally specified dynamics of the body, becoming manifest only when they acquire functional relevance within a particular action.

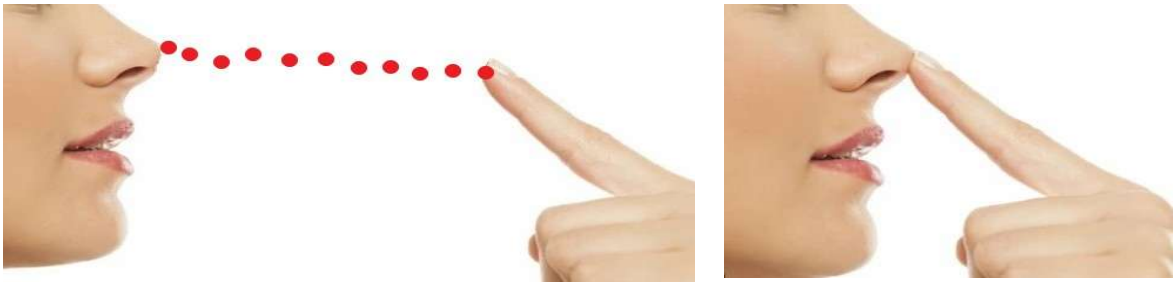
A simple illustration is provided by the children's dance *Head, Shoulders, Knees and Toes*[12]. Starting from an initial configuration in which both hands are placed on the head, action trajectory shapes can be executed from both hands toward numerous other body parts. With practice, different action trajectory shapes can even be performed simultaneously, such as movements toward the shoulder and knee, or combinations including belly–knee and ear–hip.

Within the dance itself, however, these movements are generally performed synchronously. What becomes visible is that the two arms continuously generate two autonomous yet mirrored action trajectory shapes. Although both movements remain tightly coordinated, each arm follows its own proprioceptively specified relational trajectory. The dance therefore illustrates how multiple proprioceptive action trajectory shapes can coexist and unfold simultaneously within a single organized action.

[12] https://www.youtube.com/watch?v=S2eRNzsAZg4

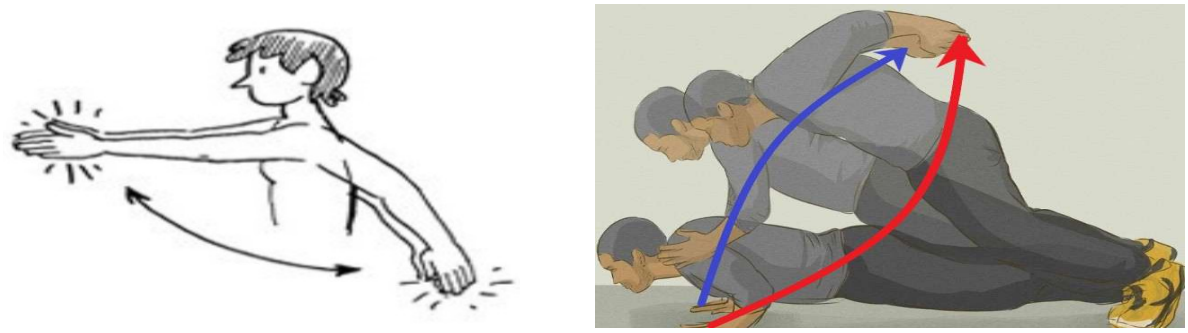
The relations between body parts continuously change throughout movement, yet actions remain stable because fluctuations within the action trajectory shapes are continuously mediated. An action trajectory shape is therefore never realized with complete precision, but remains a dynamic process of continuation, correction, and stabilization within an externally specified relational structure that is itself continuously changing.

This becomes particularly visible at the end of the dance when the index finger is brought toward the tip of the nose. At low movement speeds, the target is usually reached almost immediately. At higher speeds, however, small deviations may arise, causing the intended contact point to be temporarily missed. Larger contact surfaces, such as the palm of the hand, can accommodate such fluctuations more easily than small contact surfaces such as the fingertip, where even minimal deviations may result in observable disturbances within the unfolding action trajectory shape towards the nose. Rather than representing failures of the movement, such deviations reveal the continuously adaptive character of proprioceptive control. The movement remains organized through the ongoing mediation of fluctuations as the action trajectory shape converges toward its intended contact point.



Illustrations: *When the index finger is brought toward the tip of the nose, errors may occasionally occur because deviations within the action trajectory shape—particularly at higher movement speeds—cannot always be fully mediated. This is closely related to the size of the contact surface involved. Larger surfaces, such as the palm of the hand, can accommodate fluctuations within the action trajectory shape through a broader tolerance zone. Small contact surfaces, such as the fingertip, provide far less tolerance, so that even minor deviations may result in a temporary failure to reach the intended contact point.*

A similar principle becomes visible when clapping the hands, either in front of or behind the body. In this case, two autonomous action trajectory shapes converge toward a common point of contact. Despite the complexity of this coordination, both hands are brought together with remarkable ease because fluctuations within the two unfolding trajectory structures are continuously and mutually mediated within the same externally specified proprioceptive dynamics.



Illustrations: *It makes no difference whether we clap our hands in front of the body or behind the back. In both cases, each hand generates an autonomous action trajectory shape that converges toward a common point of intersection. Although this process can be visually observed when performed in front of the body, it is typically executed predominantly through proprioceptive perception. As the*

two action trajectory shapes unfold, the gaps between the hands progressively close and their tau-values approach zero. Because this convergence can be perceived proprioceptively with considerable precision, the timing and coordination of both movements can be continuously adjusted throughout the action. This becomes particularly evident when performing a crescendo within the clap itself, where the progressive closure of the gaps between the hands remains continuously coupled to the unfolding temporal dynamics of the movement.

Particularly important is that the approach toward this point of intersection remains directly perceivable proprioceptively as a continuous *tau*-convergence. What is perceived is not a series of separate hand positions, but the progressively decreasing relation between the two hands as the gap between them continuously approaches zero. The organism therefore does not need to internally calculate successive positions of the hands but directly follows the ongoing relational convergence as it manifests itself on the proprioceptive sensory interface.

Visual perception may support this process when available, but it is not required for successful execution. Even when visual information is absent, the complete action structure remains proprioceptively available because the relational dynamics between the body parts are already externally specified and continuously projected onto the proprioceptive sensory interface.

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5. The Complexity of the Externally Specified Structure in Proprioceptive Perception

When proprioceptive perception is analyzed systematically, it becomes apparent that the underlying structure does not consist of a collection of isolated action trajectory shapes, but of a continuous and highly extensive network of potential relations between body parts. Between every bodily segment and every other bodily segment, latent action trajectory shapes remain structurally available. These relations do not appear simultaneously as a complete totality but become selectively manifest whenever attention and action are directed toward a particular relational configuration.

Proprioceptive perception therefore does not primarily consist of integrating separate signals into a coherent whole. Rather, it concerns the activation and stabilization of relational structures that are already present within the dynamics of the body and continuously projected onto the proprioceptive sensory interface. The organism does not need to create these relations anew, but selectively couples to those that become relevant within the ongoing action.

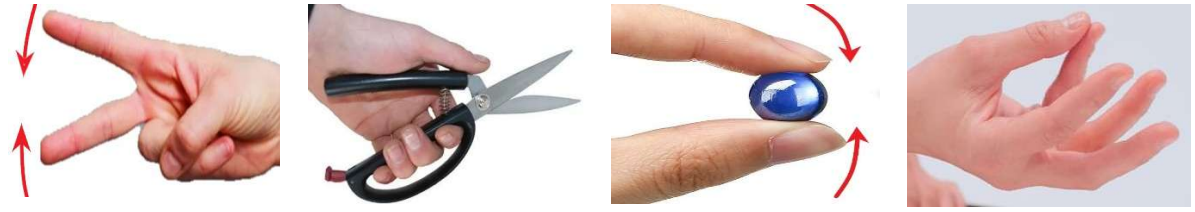
The magnitude of this relational complexity becomes apparent when attention is restricted to an apparently simple subsystem such as the hand. Even the relations between the thumb, index finger, and middle finger give rise to a large number of potential action trajectory shapes that can be realized independently, simultaneously, sequentially, or within hybrid configurations. As additional fingers, joints, limbs, and bodily segments are included, the number of potential relational structures increases drastically.

What becomes apparent is that proprioceptive perception operates within a continuously available field of relational possibilities. At any given moment only a small subset of these relations becomes functionally relevant and manifest, while the vast majority remain latent but immediately available for activation whenever the demands of the action require them[13].

[13] This principle forms the core of the explanation of the Rubber Hand Illusion (RHI). External hand perception and internal hand perception remain autonomous perceptual organizations. Only through motor action can both become functionally coupled within a common action trajectory shape. Without motor action, no genuine perceptual unification is possible: https://www.researchgate.net/publication/397770908_The_Complete_Mechanistic_Clarification_of_The_Rubber_Hand_Illusion_-_Why_External_and_Internal_Hand_Perception_Are_Autonomous_and_Cannot_Be_Unified_Without_Motor_Action

a. Hand–Fingers

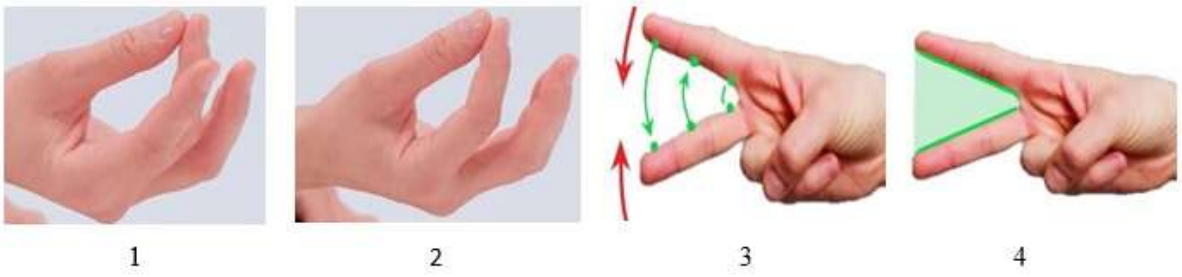
Within all subdivisions of the hand, action trajectory shapes can likewise be formed. The fingers — and even the subsegments of each finger and hand region — can be brought toward one another through specific action trajectory shapes. This underlies hand gestures, tool use, snapping the fingers and all forms of grasping. The relational dynamics of these action trajectory shapes remain continuously proprioceptively available, including their form, their tau-values[14], and the manner in which they are continuously mediated and stabilized through the cortical streams[15].



Illustrations: *Within all subdivisions of the hand, action trajectory shapes can be formed between fingers, finger segments, and different regions of the hand. These relational structures remain continuously available within proprioceptive perception and can be selectively activated depending on attentional focus and motoric goal.*

Whenever attention is directed toward specific fingers or finger segments, a perceptual image of possible relational action trajectory shapes immediately emerges. We can directly perceive when the fingers reach their maximum spread, when they begin to converge, and when complete closure is achieved. These proprioceptive experiences do not depend upon visual perception. Rather, the changing relations between the fingers remain continuously available as projected onto the proprioceptive sensory interface, allowing the unfolding action trajectory shapes to be directly perceived and followed throughout the movement.

b. Hand–Fingers II



Illustrations: *Even within the thumb–index–middle finger constellation, an enormous number of latent action trajectory shapes remain continuously available for activation. Different points, segments, and surfaces of the fingers can participate simultaneously in autonomous, hybrid, or partially coupled proprioceptive action trajectory shapes as projected onto the proprioceptive sensory interface.*

If we now focus exclusively on the possible relational configurations within the thumb–index–middle finger constellation, an extremely large number of distinct possibilities becomes apparent. The fingertips of all three fingers can be brought toward one another in multiple independent ways. The thumb and middle finger, for example, can move autonomously toward each other in either direction

[14] https://www.researchgate.net/publication/373862466_Within_grasping_the_essence_of_the_task_is_solely_executed_by_the_external_movements_of_the_fingertips_toward_a_coffee_cup_Within_the_primary_focus_the_fingertips_are_constrained_within_an_action_traj?_sg%

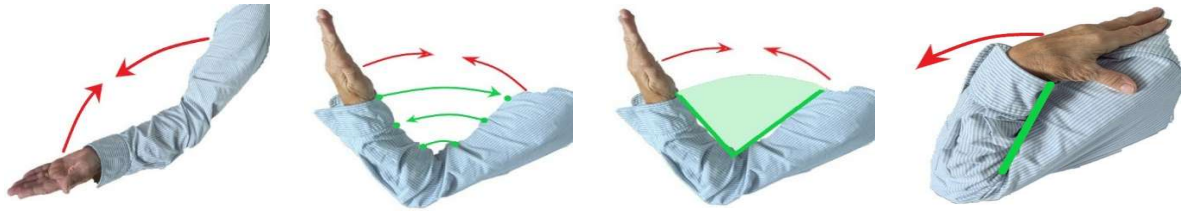
[15] https://www.researchgate.net/publication/380186699_The_explanation_of_the_emergence_of_the_cortical_streams_-_We_can_only_guide_the_fingertips_to_a_coffee_cup_with_a_zigzag_movement_yet_the_ingenious_mediation_by_the_cortical_streams_creates_the_delus

(Fig. 1), while numerous hybrid configurations between them remain equally possible. Moreover, within the relation between any two fingers, individual points along each finger (Fig. 3) can move independently in both directions, and entire surface regions can be brought into contact with one another (Fig. 4). In the latter case, complete geometric configurations may emerge, such as the shaded light-green triangle.

Crucially, attention does not project an internal image of the hand. Rather, it selectively activates latent action trajectory shapes within an already existing relational field. This becomes particularly evident during actions such as lifting a cup, handling a heavy pan, or playing the piano, where multiple autonomous action trajectory shapes must be simultaneously activated, coordinated, and stabilized between different fingers, hand regions, and environmental objects.

c. Upper Arm–Forearm

The same relational organization observed within the fingers can be found within the relationship between the upper arm and the forearm. Just as individual fingers can participate in numerous distinct action trajectory shapes, the upper arm and forearm can be related to one another through a wide range of possible relational configurations.

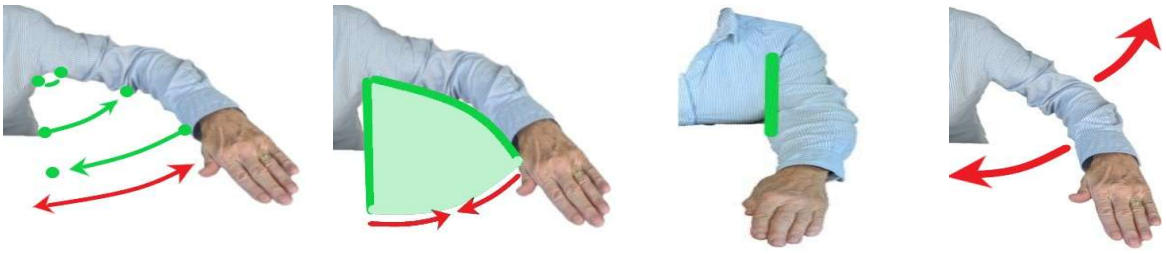


Illustrations: *The upper arm and forearm can form numerous autonomous, hybrid, and partially coupled action trajectory shapes. These relational dynamics are directly available within proprioceptive perception as projected onto the proprioceptive sensory interface and can be selectively activated depending on the requirements of the action.*

As a consequence, flexion and extension of the arm can be realized through many different relational trajectory structures. The arm therefore does not operate through a single fixed movement pattern, but through a continuously available field of relational possibilities. Within this dynamic, complete geometric configurations can emerge that remain directly available proprioceptively without requiring separate internal construction. What becomes apparent is that the same organizational principles observed within the fingers extend across progressively larger bodily segments, revealing the remarkable relational richness of proprioceptive perception.

d. Arm–Torso

The relational possibilities between the arm and the torso follow the same organizational principles as those observed between the fingers and between the upper arm and forearm. The arm can be related to the torso through a wide variety of possible action trajectory shapes, each specifying a different relational configuration within the body.



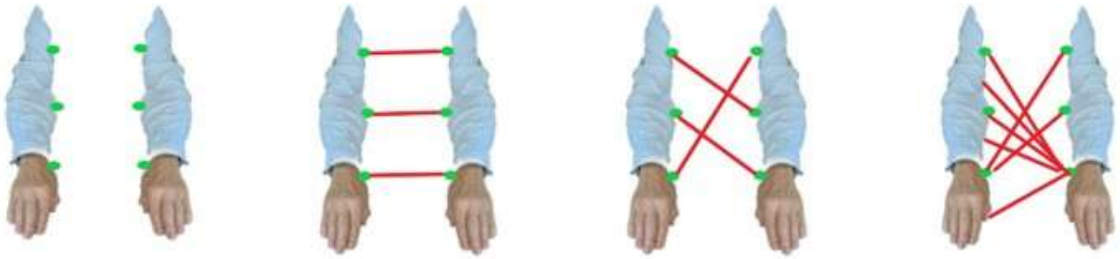
1 2 3 4

Illustrations: *Between the arm and the torso, numerous latent action trajectory shapes remain continuously available within the externally specified proprioceptive field as projected onto the proprioceptive sensory interface. Depending on attentional focus and motoric goal, different relational structures can be selectively activated and stabilized.*

As a consequence, adduction and abduction of the arm can be realized through many different relational configurations and reference points. Throughout these movements, continuously changing geometric structures emerge directly from the relational dynamics of the body itself. Once again, what appears is not a collection of isolated bodily positions, but a continuously unfolding relational field in which successive proprioceptive states remain structurally connected throughout the movement.

e. Arm–Arm I

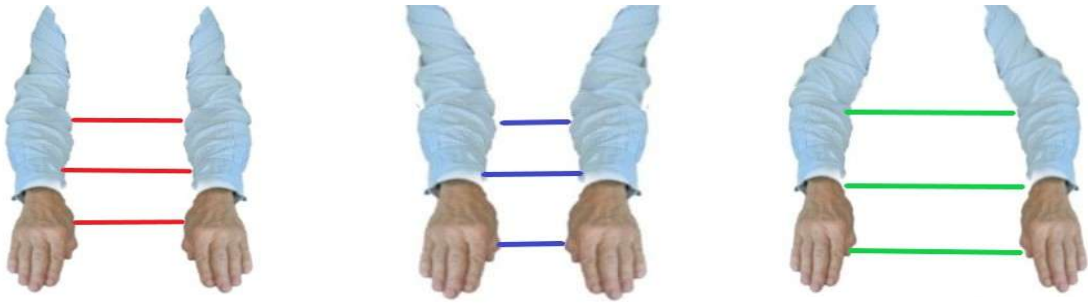
The example of clapping, discussed earlier, already demonstrated how two autonomous action trajectory shapes can converge toward a common point of intersection. When both arms are simply positioned alongside one another, however, a much richer field of relational possibilities becomes apparent. Between the two arms, an enormous number of potential action trajectory shapes remain continuously available within proprioceptive perception.



1 2 3 4

If we consider only three selected points on each arm (Fig. 1) and direct attentional focus toward them, these points can be brought toward one another in parallel and reciprocal fashion (Fig. 2). Yet the possibilities are by no means restricted to such parallel configurations. Any point on one arm can be related to any point on the other arm in a wide variety of combinations (Fig. 3). Even within this highly simplified example, the number of potential relational configurations rapidly increases (Fig. 4).

f. Arm–Arm II



1 2 3

When the two arms are positioned next to one another, we can, under attentional focus, judge the relative distances between different regions of the arms with remarkable accuracy. In doing so, we establish relational action trajectory shapes toward the opposite arm and compare the resulting proprioceptive perceptual images. It is immediately apparent that the blue line (Fig. 2) represents the shortest relational trajectory, whereas the green line (Fig. 3) represents the longest.

The perceptual image of the adduction–abduction angle undoubtedly contributes to these judgments, but it does not provide absolute information. When both arms are placed on a table in nearly identical configurations, accurate relative judgments become considerably more difficult. What remains available, however, is the proprioceptively perceived relational structure itself, through which differences in distance, orientation, and potential action trajectory shapes can still be selectively explored and compared.

g. Arm-arm III

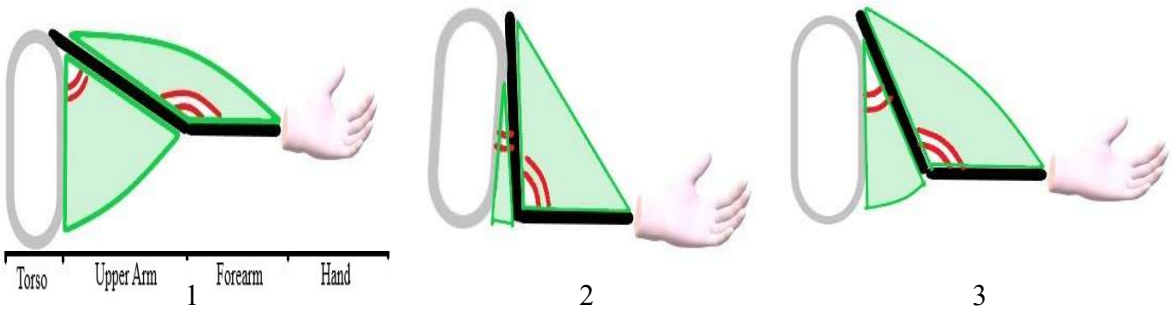
1 2 3

Even when the arms are not positioned parallel on a table, we can, without any visual information, perceive the overall form they collectively describe. This perception does not provide absolute knowledge, yet when attentional focus is directed toward the relation between the arms, clear perceptual images of their relative deviations readily emerge. Within certain limits of fluctuation, we can therefore directly perceive how different regions of one arm relate to the other and what geometric configuration arises from that relation.

What remains available throughout this process is not a collection of isolated bodily positions, but a continuously unfolding relational structure. The changing distances, orientations, and potential action trajectory shapes between the two arms remain directly accessible within proprioceptive perception, allowing them to be explored, compared, and stabilized without visual support.

h. Arm-arm IV

As a final example, we turn to the proprioceptive perception of the relational angles and geometric configurations formed by bodily segments when one arm is positioned on a table. Across the illustrated constellations, clear relative differences can be perceived in the relation between the forearm and upper arm, in the relation between the upper arm and the torso, and consequently in the overall geometric configuration collectively formed by these bodily segments. As these relations change, the entire proprioceptive organization of the configuration changes with them, giving rise to distinct perceptual images of the bodily arrangement.



1 2 3

Crucially, these relational differences do not appear as internally calculated angles or abstract representations. Rather, they remain directly available within the externally specified proprioceptive dynamics as projected onto the sensory interface. Even relatively small modifications in the relations be-

tween the forearm, upper arm, and torso can therefore be immediately perceived as changes in the underlying relational action trajectory structure and in the geometric configuration that emerges from it.

Conclusion

The preceding analyses demonstrate that proprioceptive perception does not depend upon the internal reconstruction of body positions or movements, but upon direct coupling to an already externally specified relational structure of the body as this continuously manifests itself on the proprioceptive sensory interface. The organism does not perceive isolated proprioceptive signals, but a continuously changing relational field of action possibilities within which body parts remain organized relative to one another through unfolding action trajectory shapes.

The large number of potential action trajectory shapes—even within relatively restricted subsystems such as the hand—reveals the richness of this relational organization. Between body parts, latent relational trajectory structures remain continuously available and can immediately become functionally relevant whenever attention, context, or action demands require them. Proprioceptive organization therefore does not need to be constructed anew, because the necessary relational structure is already present within the dynamics of the body itself as projected onto the proprioceptive sensory interface.

It follows that proprioceptive perception does not constitute a secondary or auxiliary system, but an autonomous perceptual domain through which externally specified relational structure becomes directly available. Visual perception may support these processes, but never fully replaces proprioceptive perception. What can be visually followed along an action trajectory shape is simultaneously perceived proprioceptively. Perception therefore emerges as a hybrid organization in which multiple sensory modalities remain continuously coupled to the same externally specified action dynamics.

The analysis of proprioceptive perception therefore further supports the central thesis of the GM. The structural organization of behavior does not originate primarily within the brain, but within externally specified dynamics as these are projected onto the sensory interface. Neural processes do not create this relational structure, but continuously follow, stabilize, and modulate the organism's coupling to an already existing field of action possibilities.

Chapter 8

The Externally Specified Structure at the Sensory Interface: Gibson and Optic Flow

Introduction

Within the history of perception research, the ecological approach of James J. Gibson represents one of the most fundamental departures from internalist and representational theories of perception. At a time when dominant scientific models regarded perception as the internal reconstruction of incomplete sensory input, Gibson radically shifted the explanatory focus toward the environment itself. Rather than understanding perception as inferential interpretation or internal reconstruction, he argued that organisms are directly sensitive to structured information already present within the ambient array (Gibson, 1966; 1979).

The exceptional significance of Gibson's work lies precisely in this shift. For the first time, it became systematically apparent that the structure organizing behavior may already exist externally and therefore does not necessarily require internal construction. A fundamental reversal was thereby achieved: perception does not primarily concern the internal organization of chaotic stimuli, but the direct coupling of the organism to an already structured external dynamics within the organism–environment relationship. Gibson demonstrated that the environment itself possesses a structural organization capable of directly guiding and constraining behavior.

This externalization of perception was most clearly elaborated through the concept of Optic Flow. Gibson showed that the visual world does not appear as a collection of isolated snapshots, but as a continuous dynamics of expansion, contraction, translation, and rotation that emerges directly from the structural relationship between organism and environment. The external world therefore does not present itself as an unordered collection of stimuli that must first acquire meaning through internal processing, but as an already structured movement dynamics that is immediately relevant for action.

Within the ecological approach, it thus became convincingly apparent that external structure can directly organize behavior. Locomotion, navigation, posture, and interception behavior were shown to be guided by the externally available structure of Optic Flow without requiring internal representations or predictive reconstructions (Turvey, Shaw, Reed, & Mace, 1981; Warren, 1988; Stoffregen & Bardy, 2001). David N. Lee demonstrated through the concept of *tau* that temporal information can be directly perceived and directly used for action (Lee, 1976; Lee et al., 1983). This revealed that organisms do not necessarily need to internally calculate future actions but can remain directly coupled to the temporal development of externally unfolding dynamics.

At the same time, one fundamental implication of this externalization remained only partially developed. Although Gibson convincingly demonstrated that the organizing structure of perception is externally located, he did not fully explicate that this external dynamics can only become behaviorally ef-

fective as it manifests itself on the sensory interface itself. The decisive organization is therefore not located merely "in the environment" in a general sense, but in the manner in which external dynamics project themselves onto the sensory surface across successive moments in time and become available there as continuously structured perceptual organization for perception and action.

It is precisely this implication that the GM makes explicit. External structure does not exist abstractly apart from the organism but appears as a continuously projected dynamics on the sensory interface itself. Successive states of both organism and environment are thereby necessarily organized into structured perceptual dynamics as they unfold across adjacent temporal units on the sensory surface. The brain does not generate this organization, but continuously follows, stabilizes, and mediates an already externally specified dynamics that unfolds directly on the sensory interface.

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1. Optic Flow versus the Gramophone Model (GM)

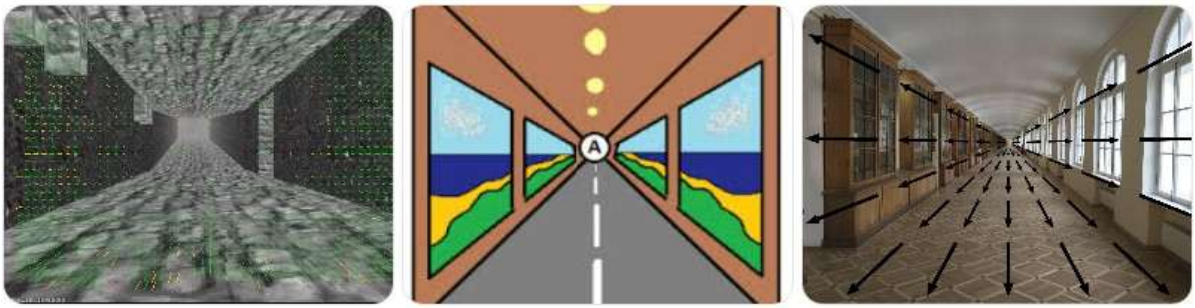
Several fundamental aspects of the underlying dynamics remain implicit within the concept of Optic Flow. This encompasses the precise temporal organization of external structure, the structural coupling of successive stimulus states, and the manner in which this organization constrains and guides motor action. Although Gibson convincingly demonstrated that the organizing structure of perception is not internally constructed by the brain, he did not fully explicate where and how this external structure becomes behaviorally effective.

Within these remaining ambiguities, it is not fully explicated that organism and environment, despite their continuous relational coupling, remain autonomous dynamical systems that each follow their own developmental trajectory within the same perception–action dynamics. Nor is it fully specified how these autonomous dynamics become continuously coupled through the sensory interface itself, where external structure becomes available for perception and action.

Likewise, it remains insufficiently developed that the movements of both organism and environment necessarily unfold as continuous action trajectory shapes in which successive positions are physically connected and become manifest on the sensory surface across successive moments in time. As a consequence, it remains implicit that the latent segment of such an action trajectory shape must necessarily emerge from its already manifest positions and is structurally constrained by the dynamics that have already been realized.

Consequently, Optic Flow primarily appears as a continuous movement structure, yet it is not fully explicated that this structure necessarily organizes itself into autonomous but mutually coupled action trajectory shapes that directly structure, constrain, and guide the further development of perception and action. This becomes particularly evident in goal-directed motor actions, where the relevant dynamics do not consist of a single integrated movement pattern, but of at least two autonomous action trajectory shapes that must be continuously coordinated: the action trajectory shape of the environmental object and the egocentric action trajectory shape of the organism itself.

When walking down a corridor, for example, Gibson convincingly describes the Optic Flow of the environment as an externally structured movement pattern. What remains largely implicit, however, is that a second autonomous dynamics is simultaneously present, namely the egocentric action trajectory shape generated by the organism itself. Both dynamics unfold in parallel within the same temporal structure and must be continuously coordinated. Perception and action therefore do not emerge from a single homogeneous visual field, but from the ongoing coordination of multiple simultaneously unfolding action trajectory shapes.



Illustrations: *When walking down a corridor, Gibson convincingly describes the Optic Flow of the environment as an externally structured movement pattern. What remains implicit, however, is that two autonomous dynamics are simultaneously involved: on the one hand, the dynamics of the environment within the Optic Flow itself, and on the other hand, the egocentric action trajectory shape generated by the organism. These dynamics do not constitute a single integrated phenomenon but unfold as autonomous action trajectory shapes within the same temporal structure. Perception and action consequently emerge from the continuous coordination of these parallel dynamics rather than from a single homogeneous flow field.*

Furthermore, it remains underappreciated that it is precisely because of this continuous line structure that meaningful statements about the further development of an action become possible at a very early stage without requiring internal reconstruction or predictive computation. Both the organism and the environmental object function as advancing actual positions within already unfolding action trajectory shapes, whereby the actual position structurally carries the further development of the dynamics. Consequently, external structure does not merely contain information about movement but directly organizes and guides the further development of perception and action itself.

Equally important is that it is not explicitly recognized that goal-directed motor actions necessarily depend upon the emergence of a point of intersection between the autonomous action trajectory shape of the organism and that of the environmental object. This implies that temporal variables, as later formalized within David N. Lee's *tau*-theory, are not singular variables referring to a single unfolding dynamics but necessarily concern the temporal coordination of multiple simultaneously unfolding action trajectory shapes converging toward a common point of intersection.

Finally, the concept of Optic Flow leaves largely implicit that neural processes do not primarily construct these dynamics but rather stabilize and mediate an already externally specified structure through continuous reciprocal feedback processes. The brain does not autonomously organize the structure of perception and action, but continuously follows, stabilizes, and modulates an already externally unfolding dynamics as it is projected onto the sensory interface.

In this sense, the concept of Optic Flow should not be regarded as an alternative to the Gramophone Model, but as its necessary historical precursor. Gibson convincingly externalized perception and thereby established a foundational insight whose importance is difficult to overestimate. The GM extends this externalization to its mechanistic and physical consequences by making explicit that externally specified structure does not exist abstractly "in the environment," but becomes behaviorally effective only as it is continuously projected onto the sensory interface. It is there that successive states of organism and environment become structurally coupled and organize themselves into continuous action trajectory shapes that directly structure, constrain, and guide the unfolding of perception and motor action.

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2. Optic Flow within the Explanatory Model of the Motoric Movement Action

The preceding analysis makes clear that Optic Flow cannot be understood as a singular visual phenomenon, but rather as a structured dynamics in which the movements of organism and environment must necessarily be analyzed in relation to one another. Within Gibson's ecological approach, however, this dynamics largely remains implicit at the level of a single integrated visual pattern, without an explicit specification of the underlying organization of motor action itself.

Within the explanatory model of the motoric movement action, this dynamics is systematically specified as the manifestation of underlying action trajectory shapes within which both the environmental object and the organism develop autonomously and simultaneously. Optic Flow therefore does not constitute the explanatory principle itself, but rather the directly perceivable result of a deeper externally specified temporal organization that is continuously projected onto the sensory interface.

From this perspective, every motor action necessarily depends upon the coordination of at least two autonomous action trajectory shapes: the action trajectory shape of the environmental object and the egocentric action trajectory shape of the organism. These trajectory structures develop independently yet must simultaneously become coordinated within a common point of intersection. The actual position within these trajectory shapes functions not merely as a manifest position, but also as a projective boundary from which the further development of the dynamics necessarily unfolds.

Illustrations: *The depicted patterns show the transformation of the optic array during movement through the environment, as originally described by James J. Gibson. These patterns of expansion and transformation constitute what Gibson termed Optic Flow: the systematic change of visual information as a consequence of movement. The expansion and transformation of the visual field thereby specify the direction and structure of movement as a continuous dynamics unfolding through time.*

From this perspective, it becomes apparent that perception does not depend upon reconstructing discrete states of the world, but upon directly following an already externally specified dynamics in which each actual position structurally carries the further development of the unfolding process. External structure therefore does not merely provide information about movement but directly organizes and guides the further development of perception and action itself.

Within this framework, the *tau*-value acquires a different status[16]. *Tau* is not an isolated temporal variable, but the expression of the relational temporal organization between multiple simultaneously unfolding action trajectory shapes converging toward a common point of intersection. Prediction and anticipation therefore do not arise through internal reconstruction but emerge as a direct consequence of the externally specified continuity of the action trajectory shape itself.

Against this background, it becomes apparent that the ecological analysis of Optic Flow comes remarkably close to a mechanistically coherent account of perception and action. The externalization of information and the emphasis on continuous change provide a powerful and highly influential foundation. At the same time, the underlying temporal organization of this dynamics remains implicit as long

[16] A detailed analysis of D. N. Lee's *tau* theory and the role of *tau*-values within the GM is provided in the next chapter.

as external structure is not explicitly specified in terms of continuous action trajectory shapes that become manifest on the sensory interface across successive moments in time and from there directly structure, constrain, and guide the unfolding of perception and motor action.

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3. The Full Specification of Optic Flow within the Gramophone Model

The preceding sections have established that Optic Flow cannot be understood as a singular visual phenomenon, but rather as the manifest projection of an underlying externally specified dynamics in which the autonomous egocentric movement of the organism and the autonomous movement within the environment are necessarily related to one another. Within the GM, this dynamics is no longer approached merely descriptively but is systematically specified in terms of continuous action trajectory shapes that become manifest on the sensory interface across successive moments in time.

This specification makes explicit that Optic Flow does not constitute a single homogeneous phenomenon but consists of multiple simultaneously unfolding and mutually coupled dynamics. In particular, the GM introduces a fundamental distinction between Environmental Optic Flow (EOF) and Egocentric Optic Flow (EGOF). EOF concerns the externally specified action trajectory shapes of environmental objects as they are projected onto the sensory interface, whereas EGOF refers to the egocentric action trajectory shapes, also projected at the visual sensory interface, generated by the organism itself. Although both domains remain autonomous, they necessarily converge within every motor action.

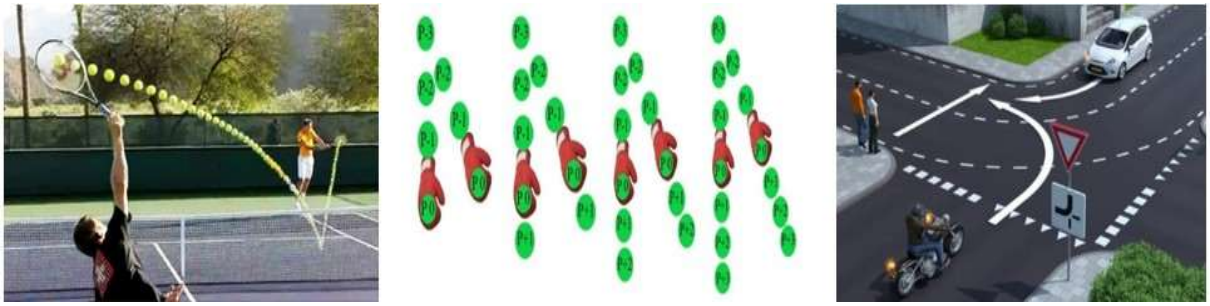
Within this dynamics, successful action emerges only when EOF and EGOF become coordinated at a common point of intersection. The actual position within these action trajectory shapes functions not only as a manifest position, but also as a projective boundary from which the further development of the dynamics necessarily unfolds. External structure therefore does not merely contain information about movement but directly organizes and guides the further development of perception and action itself.

Optic Flow will therefore be systematically analyzed through three complementary dimensions: 1. Environmental Optic Flow (EOF) will be examined, focusing on the externally specified action trajectory shapes of environmental objects. 2. Egocentric Optic Flow (EGOF) will be discussed, focusing on the egocentric action trajectory shapes generated by the organism itself. 3. Composite Optic Flow (COF) will be introduced, demonstrating how these two autonomous dynamics must be continuously coordinated within complex perception–action processes.

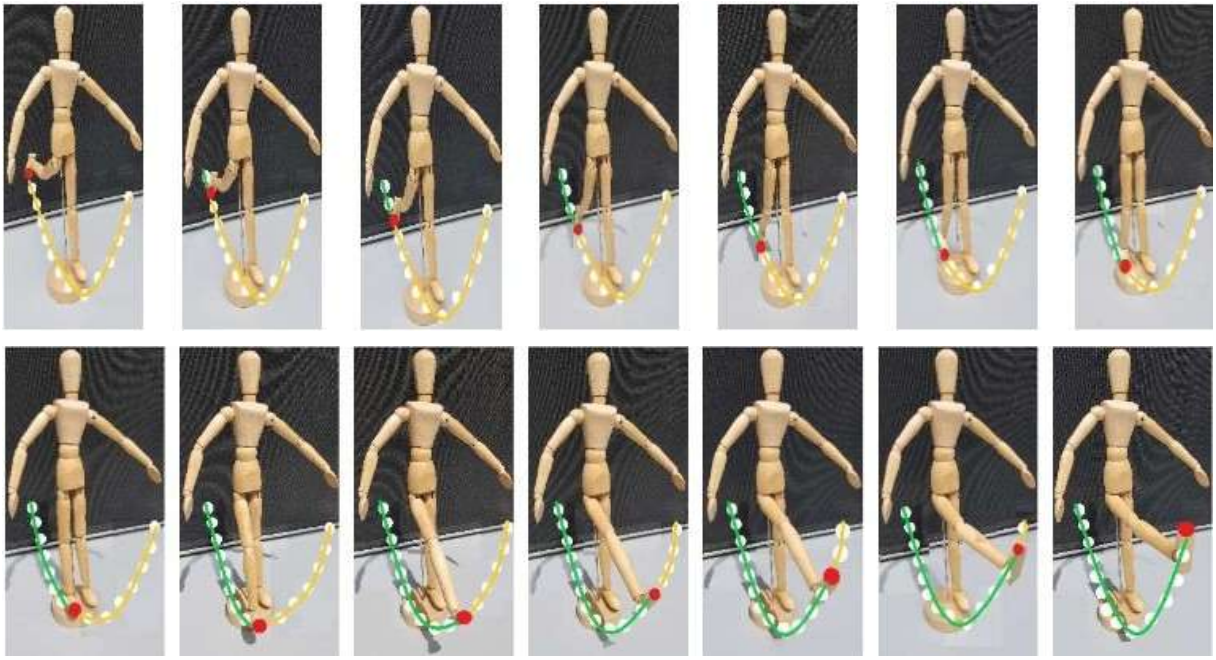
a. Environmental Optic Flow (EOF) in Relation to Actual Moving Environmental Objects

All movement is relative. An approaching cyclist, for example, is perceived as an actual moving object, yet this distinction disappears as soon as we ourselves begin cycling. Within the explanatory model of the motoric movement action, perception consists of a continuous comparison process of successive adjacent time units as these are continuously projected onto the sensory interface. This implies a permanent catch process of the perceptual dynamics itself, whereby the bicycle, during self-cycling, is perceived as a zero-movement and, as it were, becomes captured within the ongoing perceptual dynamics.

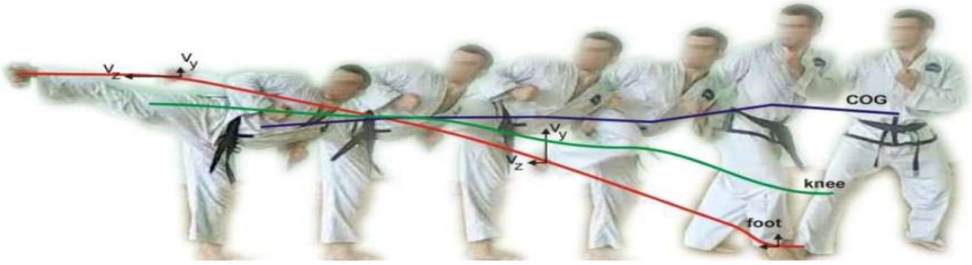
Environmental Optic Flow (EOF) therefore concerns the externally specified action trajectory shapes of environmental objects as they continuously become manifest on the sensory interface. Successive positions of environmental objects do not appear as isolated stimuli, but as necessarily connected elements within continuous action trajectory shapes whose further development is directly available for perception and action.



The explanatory model of the motoric movement action has demonstrated across a wide range of motor activities that perception necessarily organizes successive adjacent time units into continuous action trajectory shapes. This becomes visible in a broad variety of behaviors, including grasping, writing, eating, opening a lock with a key, sporting actions such as tennis and combat sports, and behavior in traffic. The same principle becomes particularly evident in everyday computer use, especially in the computer game Pong, as well as in auditory processes.

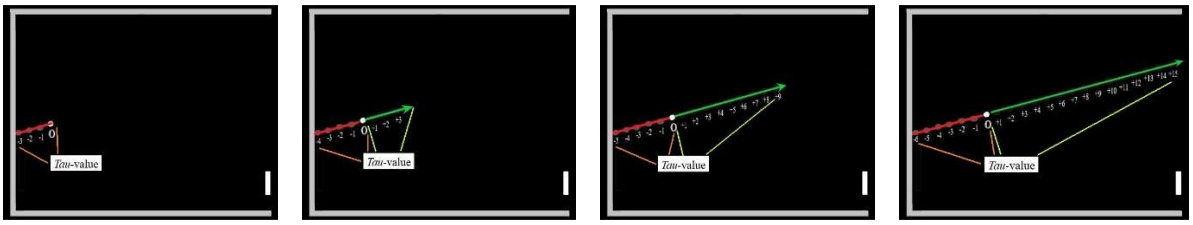


Across all of these examples, it becomes apparent that successive positions of an external environmental object cannot exist independently of one another but must necessarily emerge from one another and therefore remain structurally connected within a single continuous action trajectory shape. Every environmental object is consequently organized within an externally specified line structure as this continuously projects itself onto the sensory surface. This implies that all manifest positions—for example, those of a foot during a combat action—together constitute a single action trajectory shape in which the actual position continuously forms the leading edge of the manifest segment, while the latent segment necessarily emerges from the trajectory that has already been realized.



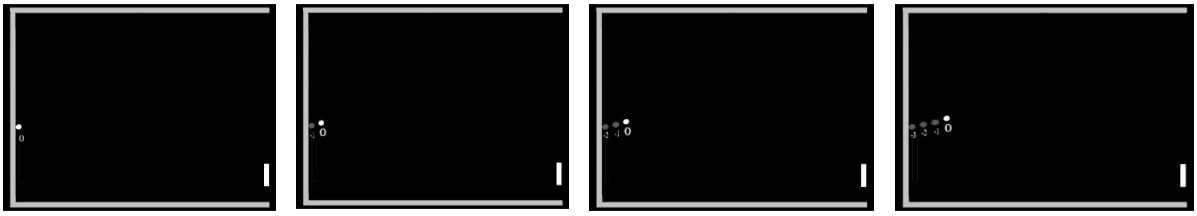
In this way, a global action trajectory shape can already be perceived at an early stage of the action on the basis of all manifest positions of, for example, a foot, a tennis ball, or a Pong ball. The actual position P(0) continuously forms the precise boundary between the manifest and latent segments of the trajectory, analogous to a marble in a marble run, where the current position already structurally carries the further course of the track. Only by situating the movement of the object within this complete action trajectory shape does it become possible to understand the development of the *tau*-value, which is based on the perception of the progressively diminishing distance within the latent segment of the trajectory. At the same time, this organization makes visible how cortical processes necessarily stabilize and mediate deviations within this externally specified dynamics.

Against this background, it becomes clear that the game Pong[17] provides a particularly suitable context for making the operation of EOF explicitly visible. Within this highly constrained and systematically organized situation, the formation and continuation of action trajectory shapes, as described above, can be directly observed and followed in a controlled manner.



The perception of the Pong ball illustrates the fundamental interception process that is present in every conceivable motor action involving an environmental object. As soon as a limited number of successive manifest positions become available, perception gives rise to an implicit action-relevant projection of the further course of the trajectory on the sensory interface. This projection does not arise from conscious computation or complete visual information but emerges directly from the externally specified continuity of the movement itself.

At the initial appearance of the Pong ball, no coherent structure is yet available. However, as soon as multiple successive positions become manifest, these positions necessarily become organized into a continuous action trajectory shape, giving rise to a perceptual image of an unfolding trajectory that extends beyond the immediately visible information. This projection is not exact in detail, but sufficiently precise to specify the global form of the action trajectory shape.

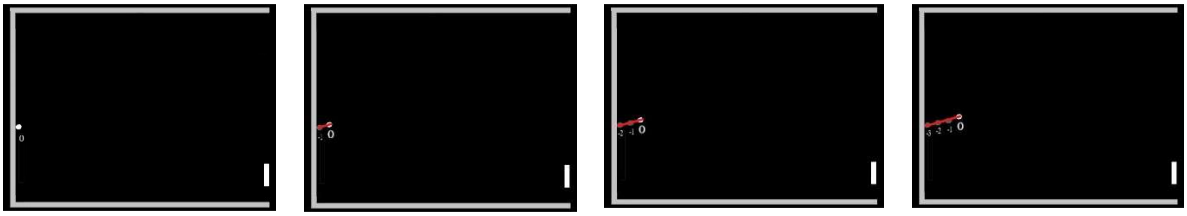


1 2 3 4

Crucially, this process rests on the fact that all successive positions belong to one and the same object moving through space. Because these positions necessarily belong to the same object, they cannot exist as independent events but must be organized within a continuous action trajectory shape. Within this structure, the current position continuously forms the leading edge of the manifest trajectory while

[17] https://www.researchgate.net/publication/393795043_All_functional_perception_processes_in_relationship_to_PONG?_sg%5B0%5D=MWLOACaRyovQ-Qutu-udxE0V_rpgcFIWF1Y4-NxwJogcOAnYInwhV-4wfisP1HMKCFL5dxaUm33S-qNWu8uurkvq8fq5nxLwISak3zWw.qB--dcOSexBo7MiS-jTZMKzlmNsVZYKiQfBDJKPb8TNszhc7KxekMrUvJVSi67-CcMqJPv09D3uDPA-d5KAm8GA&_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6ImhvbWUiLCJwYWdlIjoicHJvZmlsZSIsInByZXZpb3VzUGFnZSI6InByb2ZpbGUiLCJwb3NpdGlvbiI6InBhZ2VDb250ZW50In19

simultaneously constituting the precise boundary between the manifest and latent segments of the action trajectory shape.



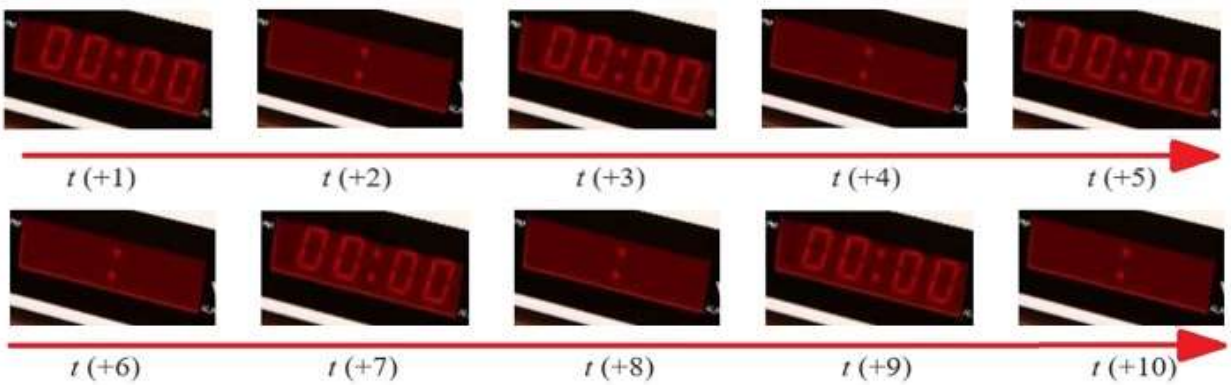
1 2 3 4

Within this framework, the early emergence of such an action trajectory shape simultaneously allows for the projection of the egocentric movement required to intercept the ball. Prediction therefore does not arise from an internal reconstruction of future states but emerges as a direct perceptual consequence of the externally specified continuity of the trajectory itself as it is projected onto the sensory interface. The temporal dimension of this process becomes explicitly accessible through the *tau*-value, which expresses the progressive reduction of the gap within the latent segment of the action trajectory shape until the moment of contact.

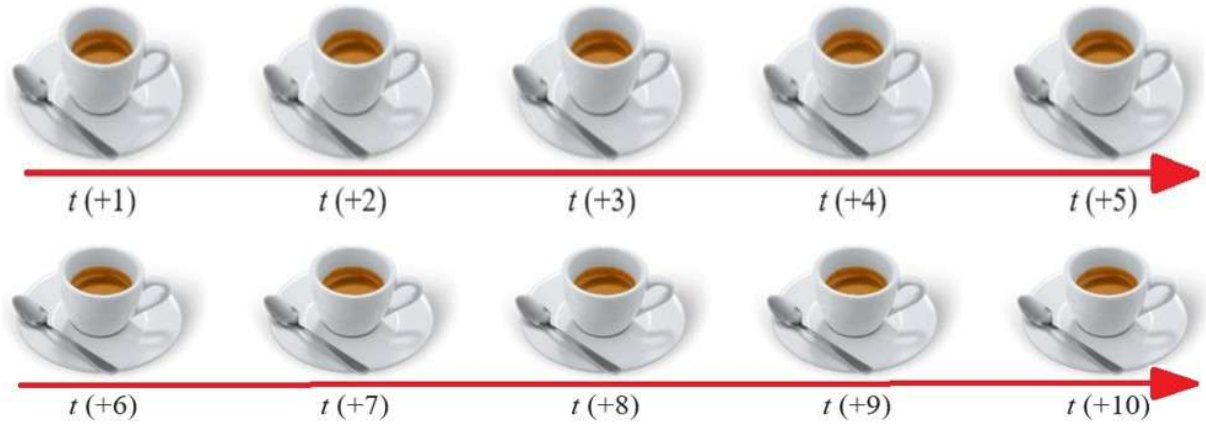
b. Environmental Optic Flow (EOF) in Relation to Stationary Environmental Objects

The explanatory model of the motoric movement action has likewise demonstrated in detail how stationary environmental objects are perceived. Contrary to conventional assumptions, stillness does not constitute a separate perceptual domain but is perceived within the same externally specified dynamics as movement. Consequently, no fundamental distinction exists between the perception of a stationary object and that of a moving object. Even under conditions of stillness, perception continues to consist of a continuous comparison of successive adjacent time units as these are projected onto the sensory interface across time.

Consider the example of a digital clock whose zeros flash following a power outage. Each successive appearance of the zeros occurs at the same spatial location, while each observation remains temporally distinct from the previous one. The perception of these zeros therefore does not arise from a persistent visual state, but from the continuous comparison of successive observations that are related solely through their identical spatial position. What is perceived as stillness thus emerges as a special case of the same externally specified dynamics that underlies movement, namely a situation in which temporal succession continues while spatial displacement remains absent.



In an identical manner, a stationary coffee cup is perceived not as a static entity, but as a sequence of temporally successive observations that do not directly relate to one another except through their invariant spatial configuration, whereby the absence of positional change across these successive observations leads to the conclusion that the object is stationary, even though the underlying perceptual process remains fully active and structurally identical to that involved in perceiving relative movement.



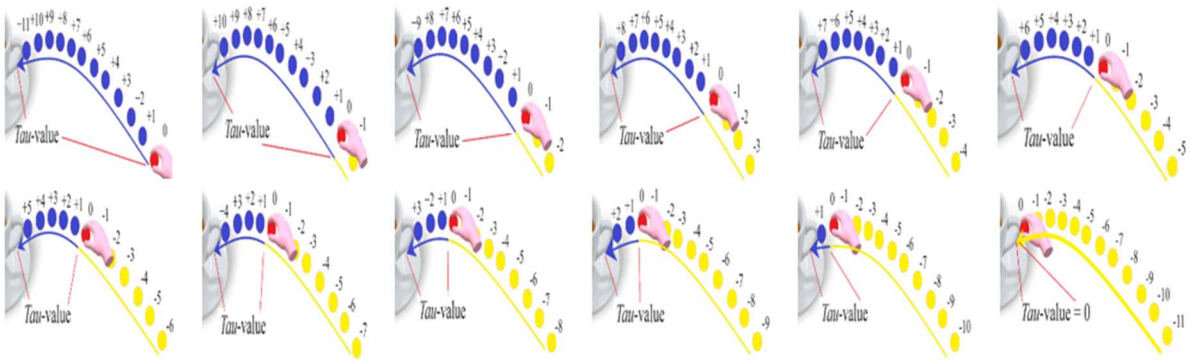
Within the GM, this makes visible that stillness does not constitute the absence of dynamics, but a specific form of EOF in which successive positions of the environmental object continue to become manifest at the same location within the action trajectory shape. The comparison of successive adjacent time units therefore remains just as active as in the perception of actual movement, with the crucial difference that no positional displacement of the environmental object is detected. The object consequently occupies a zero-movement action trajectory shape, within which the *tau*-value remains structurally zero.

Any goal-directed motor action—such as grasping a coffee cup—therefore necessarily requires the organism to develop an egocentric action trajectory shape that becomes coordinated with this zero-movement trajectory as both are simultaneously projected onto the sensory interface. Successful action thus arises not from internal reconstruction, but from the direct coordination of an egocentric action trajectory shape with an already externally specified EOF.

c. Egocentric Optic Flow (EGOF) in Relation to a Moving Body Part

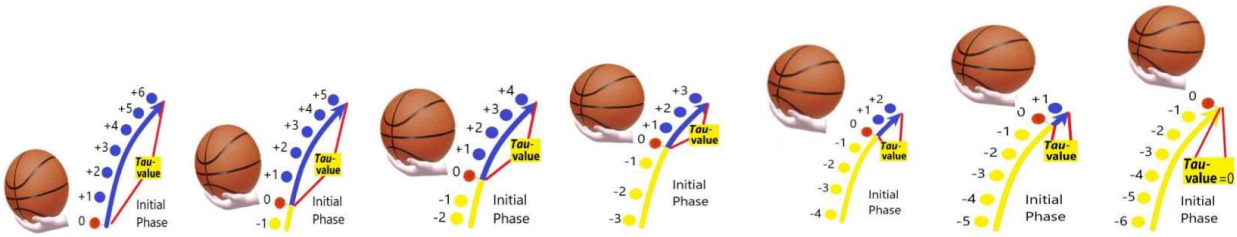
Although Optic Flow is formally defined by Gibson as a relational phenomenon that emerges directly from the movement of the organism within the environment, its elaboration within the literature and its dominant interpretation have become primarily focused on the movement structure of the environment (EOF). Consequently, the egocentric component (EGOF) of this externally specified dynamics, as it continuously projects itself onto the sensory interface, has remained conceptually underdeveloped, partly because motor actions have generally been treated as a single undivided process.

Within the explanatory model of the motoric movement action, this omission is explicitly corrected by demonstrating that the egocentric movement of the organism cannot be understood as a derivative of environmental dynamics. Instead, it constitutes an autonomous action trajectory shape that develops in parallel with, and in necessary relation to, the action trajectory shape of the environmental object. Egocentric Optic Flow (EGOF) therefore concerns the externally specified egocentric action trajectory shapes as these continuously become manifest on the sensory interface.

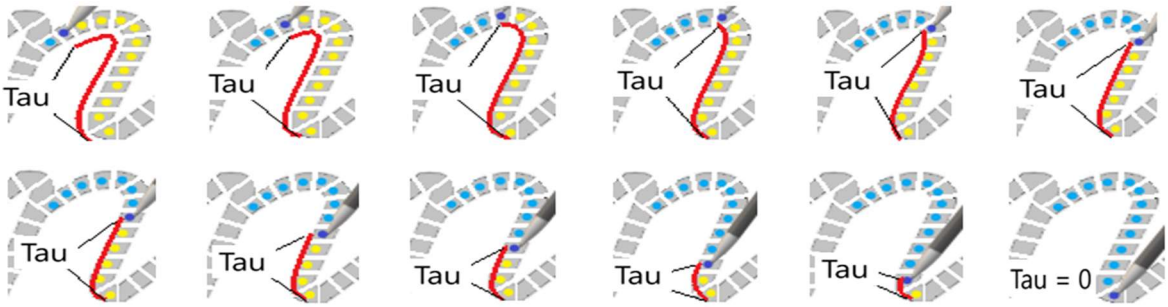


Within EGOF, a first fundamental category becomes visible in which parts of the body move through space as observable action objects. An arm, hand, or leg can thereby function as the action object and can be visually perceived as a moving element within the vista, analogous to a marble moving through a marble run. This movement does not constitute an internally generated motor sequence, but an externally specified action trajectory shape in which successive positions necessarily emerge from one another and become organized into a continuous line structure.

This becomes visible across a wide range of motor activities, including grasping, writing, eating, posting a letter, opening a lock with a key, tennis serves, basketball free throws, golf swings, and more specialized tasks such as the nerve spiral game[18]. In all these cases, movement does not emerge from an internal motor script, but from the continuous coordination of the egocentric action trajectory shape with the externally specified dynamics as these project themselves onto the sensory interface.



Illustrations: *Grasping a coffee cup, writing, or executing a basketball free throw demonstrates that egocentric movements are organized according to the same fundamental principle. In each case, the moving body part follows a continuous action trajectory shape in which every new position necessarily emerges from the preceding one. What is often described as predictive coding does not constitute a separate process but reflects the perception of this continuously unfolding movement itself. Perception and movement therefore do not operate as independent processes, but as different aspects of one and the same continuously developing action trajectory shape. Within EGOF, this movement does not constitute a derivative of environmental dynamics, but an autonomous phenomenon in which successive positions of the action object necessarily emerge from one another and become organized into a continuous action trajectory shape according to the same structural principles that govern EOF.*



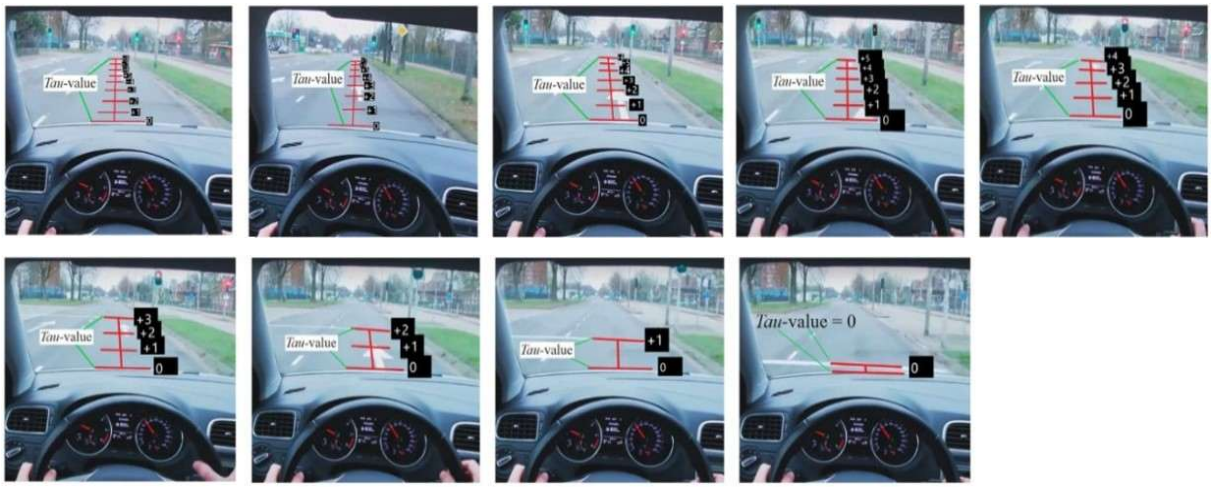
Within this dynamics, the same structural principles remain operative. The actual position continuously occupies the leading edge of the manifest segment, the latent segment necessarily develops from the manifest segment, and the actual position P(0) forms the precise boundary between the two. The development of the action trajectory shape is characterized by the *tau*-value as the temporal expression of the progressively diminishing distance to the point of intersection. Only by understanding the movement as a whole—as a marble moving through a marble run—does it become possible to understand how cortical processes stabilize and mediate the deviations that arise within this externally specified structure.

[18] https://www.explanatorymodel.nl/common-daily-actions

From this perspective, EGOF does not constitute a separate motor domain alongside perception, but a directly perceivable manifestation of the same externally specified perception–action dynamics within which perception and action remain continuously coordinated through the ongoing projection of the action trajectory shape onto the sensory interface.

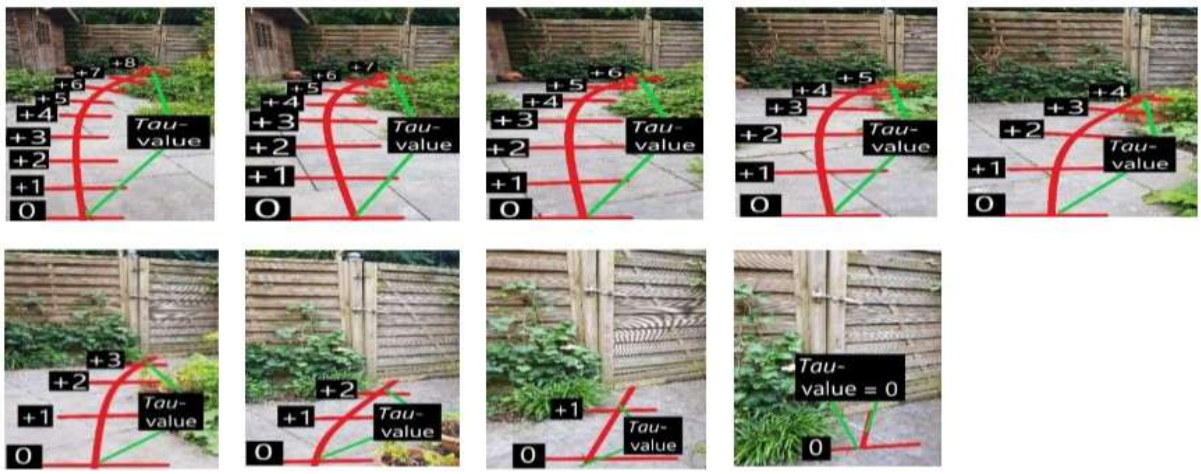
d. Egocentric Optic Flow (EGOF) in Relation to the Movement of the Whole Body

In addition to situations in which individual body parts function as action objects, a second fundamental category must be distinguished within EGOF. During walking, cycling, rowing, or driving, the organism as a whole participates in the movement, such that the entire body itself becomes the reference point from which the externally specified dynamics unfolds.



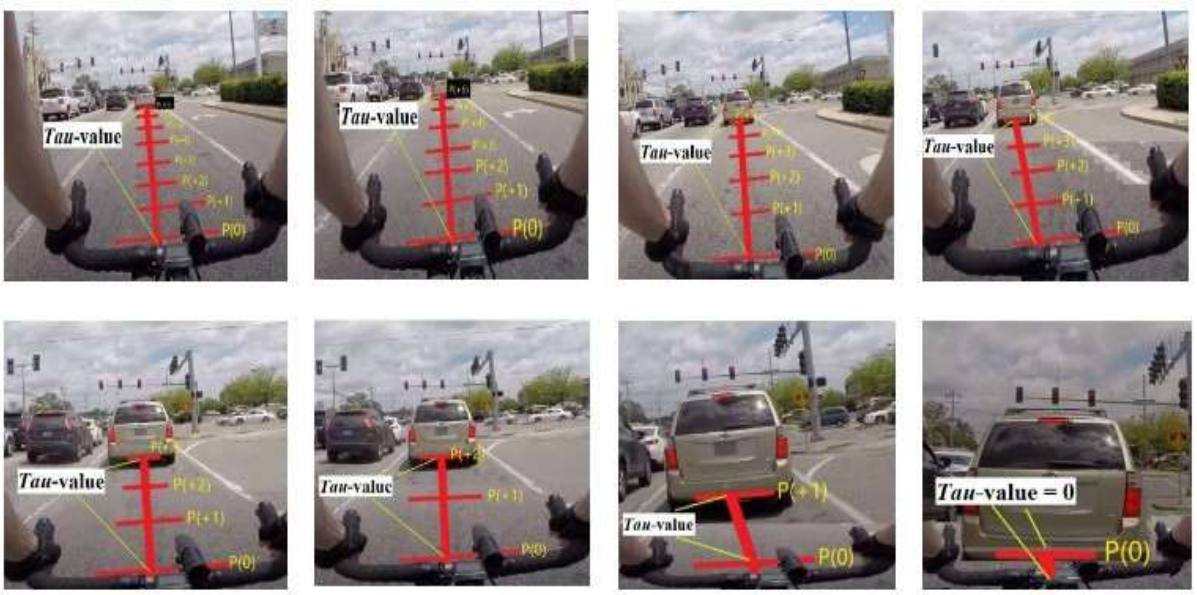
Perception is therefore no longer directed primarily toward an externally moving object, but toward one's own progression within the action trajectory shape as it continuously projects itself onto the sensory interface. The organism continuously forms the actual position P(0) from which the movement develops, while the dynamics is experienced as the progressive reduction of the distance to a target or point of intersection. In this sense, perception no longer concerns the observation of an externally moving object, but the direct experience of one's own progression within the externally specified structure itself.

Within this form of EGOF, the action trajectory shape does not emerge from discrete motor commands, but from the continuous temporal organization of the externally specified dynamics as it becomes manifest on the sensory interface. Successive positions of the organism cannot exist independently of one another but must necessarily emerge from one another and therefore remain structurally connected within a single continuous egocentric action trajectory shape.



Illustrations: *The animations of driving a car, walking toward a garden gate, and cycling toward a stationary car at a traffic light demonstrate that, when the organism as a whole is moving, a fundamental shift in perspective occurs. Perception shifts from following an externally moving object to experiencing one's own progression within the action trajectory shape. In all three cases, the organism itself forms the actual position P(0), while the trajectory extends toward the relevant object, and the dynamics is experienced as the continuous reduction of the distance to the point of intersection—not as external movement, but as one's own progression within the externally specified structure.*

We can perceive a bobsled moving through a bobsled track, a walker progressing along a path, or a long jumper during the run-up to the take-off board as environmental objects. However, we can also perform these actions ourselves, in which case the perspective reverses. Instead of perceiving an object moving along an action trajectory shape, perception coincides with our own progression along that trajectory. This is more difficult to visualize because, in such situations, we are no longer observing the marble moving through the marble run—we become the marble itself.



Here again, the same structural principles remain operative. Successive positions are necessarily connected, the actual position continuously forms the leading edge of the manifest segment, the latent segment necessarily develops from the manifest segment, and the *tau*-value expresses the temporal structure of the approaching point of intersection. Successful motor action can therefore only be achieved when the egocentric action trajectory shape is continuously coordinated with the action trajectory shape of the environmental object as both are simultaneously projected onto the sensory interface.

This makes visible that, even when the whole body is moving, perception and action do not constitute separate processes but represent manifestations of one and the same externally specified perception–action dynamics. The organism continuously stabilizes its own progression within an already externally organized structure, not through internal reconstruction, but through ongoing coupling to the externally specified dynamics as these unfold on the sensory interface.

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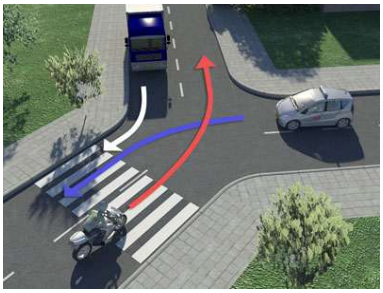
4. Composite Optic Flow – The Interplay of EOF and EGOF

In the preceding sections, Environmental Optic Flow (EOF) and Egocentric Optic Flow (EGOF) were analyzed separately. Within every actual motor action, however, these dynamics never occur in isolation and must necessarily be understood in relation to one another. Every action depends upon the simultaneous development of two autonomous action trajectory shapes: the action trajectory

shape of the environmental object and the egocentric action trajectory shape of the organism itself. Composite Optic Flow therefore concerns the necessary structural coupling between EOF and EGOF as both become simultaneously manifest on the sensory interface.





Illustrations: *Complex traffic perception does not depend upon separate internal calculations of isolated objects, but upon the continuous perceptual coordination of multiple autonomous action trajectory shapes as these simultaneously become manifest on the sensory interface. Within this complex dynamics, visual tau-values do not arise independently, but as components of a single integrated perceptual field in which all relevant action trajectory shapes are continuously organized in relation to one another.*

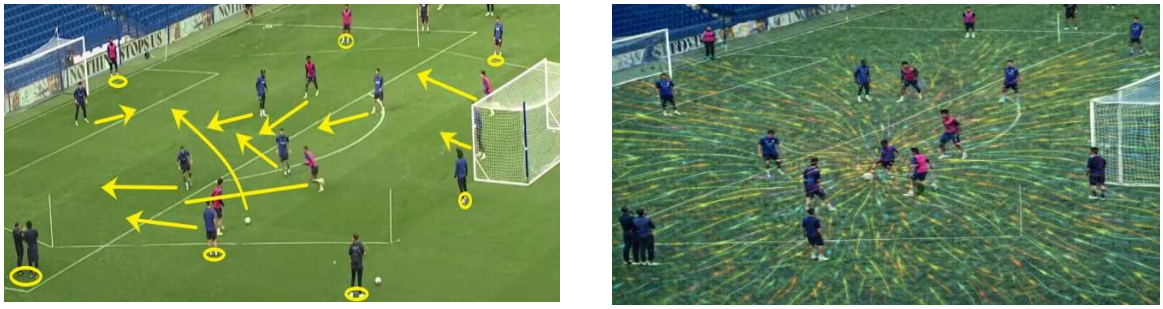
These action trajectory shapes develop autonomously yet remain structurally related because successful action can emerge only when both dynamics become coordinated at a common point of intersection. Perception therefore does not consist of two separate processes, but of a single composite perception–action dynamics within which the organism continuously follows, stabilizes, and modulates the relational organization between both action trajectory shapes.



Illustrations: *Across all examples, the central phenomenon is not the perception of isolated objects or discrete movements, but the continuous projection of multiple action trajectory shapes onto the sensory interface itself. Within Gibson's ecological approach, the analysis largely remains focused on the visible structure of Optic Flow. Within the GM, by contrast, it is made explicit that this projection onto the sensory interface constitutes the central organizing boundary at which perception and action remain continuously coordinated. The brain does not function as the primary generator of this structure, but as a stabilizing and mediating system that continuously follows, stabilizes, and modulates the externally specified dynamics through reciprocal feedback processes.*

Within Composite Optic Flow, both the organism and the environmental object continuously occupy the actual position P(0) of their respective action trajectory shapes, while the latent development of both trajectories necessarily emerges from their already realized positions. From these actual positions, perception can continuously follow the approach toward the common point of intersection. The *tau*-values of both dynamics therefore do not exist independently but remain intrinsically coupled within a single integrated temporal structure.

Motor action therefore does not emerge from a single trajectory, but from the necessary coordination of multiple autonomous action trajectory shapes that must be continuously brought into alignment. The organism does not autonomously generate this dynamics but remains continuously coupled to an already externally specified structure as this projects itself onto the sensory interface. Perception and action consequently converge in the realization of the common point of intersection between EOF and EGOF.



Illustrations: *The examples of marathon running, combat sports, and football demonstrate that Composite Optic Flow extends across a large number of simultaneously unfolding action trajectory shapes that must continuously be coordinated. In marathon running, this concerns the coordination between one's own progression, the course, and other runners; in combat sports, the continuous relational dynamics between one's own movements and those of the opponent; and in football, the complex organization involving player, ball, teammates, and opponents. Consequently, multiple potential points of intersection arise simultaneously, rendering the dynamics considerably more complex while leaving the underlying structural principles unchanged.*

Within an actual vista, this principle becomes visible across a multitude of simultaneously unfolding action trajectory shapes, in which multiple environmental objects and egocentric movements develop in parallel and are continuously perceived in relation to one another. This does not make the dynamics fundamentally different but rather confirms that all perception and action depend upon the same necessary organization of successive positions into continuous action trajectory shapes. The organism thereby remains continuously coupled to multiple potential points of intersection within a single composite externally specified dynamics as this continuously becomes manifest on the sensory interface.

Conclusion

James J. Gibson's ecological approach marks a fundamental shift in the understanding of perception by unambiguously externalizing perception and grounding it in the dynamics of the environment. In doing so, it established a decisive break with internalist explanatory frameworks in which perception was understood as a process of internal reconstruction. This externalization represents an essential and highly influential step that laid the foundation for a new understanding of the relationship between organism and environment.

At the same time, it must be recognized that Gibson's formulation of Optic Flow remains at a relatively global and underspecified level. Although he convincingly demonstrated that perception is sen-

sitive to structured change within the environment, the precise organization of this structure was not fully explicated. This becomes apparent, among other things, from the fact that fundamental temporal variables such as the *tau*-value were only explicitly formulated in later work, indicating that the underlying dynamics remained incompletely specified within the original concept of Optic Flow.

More fundamentally, Optic Flow in Gibson's work is implicitly approached from a single dominant focus, namely the movement structure of the environment as it appears within the visual field. Although Gibson formally acknowledged the relational nature of perception, the egocentric component remained conceptually underdeveloped, and motor action was generally treated as a single undivided process. Yet every actual motor action necessarily involves the simultaneous development of two autonomous action trajectory shapes: the trajectory structure of the environmental object and the egocentric trajectory structure of the organism itself. This dual organization is not a secondary feature, but the structural prerequisite for the emergence of a point of intersection at which the action can be realized. Because this dual structure was not explicitly distinguished within Gibson's formulation, the coordination between these dynamics—and thus the core of motor action itself—remained underspecified.

Although the concept of Optic Flow originally refers to visual dynamics, the explanatory model of the motoric movement action demonstrates that the underlying organization of perception is not modality-specific. The organism receives a continuous spectrum of externally specified dynamics that manifests itself simultaneously across multiple sensory interfaces. The distinction between visual, auditory, haptic, and proprioceptive perception therefore does not reflect a fundamental difference in the external structure itself, but rather a biological differentiation of the same underlying external dynamics across different sensory systems. Optic Flow consequently no longer appears as an isolated visual principle, but as one particular manifestation of a more general externally specified organizing principle underlying all perception and action.

Within the explanatory model of the motoric movement action, this limitation is addressed by explicitly specifying perceptual dynamics in terms of action trajectory shapes. This makes visible that successive positions of every object within the vista are necessarily connected and organize themselves into continuous trajectory structures as these become manifest on the sensory interface across successive moments in time. This organization is not a descriptive property of perception, but a structural property of the external dynamics itself, within which every position necessarily emerges from the preceding one. The latent segment of the action trajectory shape cannot be separated from the manifest segment, but must necessarily emerge from it, such that the further development of the dynamics is already contained within the actual position itself.

What is absent from Gibson's formulation is therefore not merely additional detail, but the explicit formulation of necessity. Within the explanatory model of the motoric movement action, the organization of successive positions does not constitute a descriptive regularity, but a necessary structural property of external dynamics itself. Successive positions cannot exist independently but must necessarily emerge from one another and organize themselves into continuous action trajectory shapes. Optic Flow thereby shifts from an empirical observation to a physically necessary principle that directly structures, constrains, and guides the unfolding of perception and action.

In this light, Gibson must be regarded as having taken a necessary first step by identifying the external basis of perception, while his formulation of Optic Flow represents only the beginning of a far more precise specification of the underlying dynamics. Only within the explanatory model of the motoric movement action does it become visible that this dynamics is not merely external, but also structurally specified and necessarily organized. Optic Flow therefore appears not as an endpoint, but as an initial approximation of a more general principle in which perception and action are necessarily organized

through continuous externally specified action trajectory shapes that become manifest on the sensory interface and from there directly structure, constrain, and guide the unfolding of behavior.

Chapter 9

The Externally Specified Structure on the Sensory Interface – Lee and the Tau-Value

Introduction

James J. Gibson's ecological approach marks a fundamental shift in the understanding of perception by unambiguously externalizing perception and grounding it in the dynamics of the environment. In doing so, it established a decisive break with internalist explanatory frameworks in which perception was primarily understood as a process of internal reconstruction, inference, or representation formation. Within this approach, it became apparent that the information organizing behavior can already be present in the external world and directly available for perception and action.

Within the highly influential concept of Optic Flow, Gibson demonstrated that perception is not based on isolated static images, but on continuous patterns of change that arise directly from the relational dynamics between organism and environment. For the first time, this made it systematically visible that behavior can remain directly coupled to externally structured dynamics without requiring the assumption of an internal model.

At the same time, Gibson's externalization remained largely at a descriptive level. Although he convincingly demonstrated that perception is sensitive to continuous external change, the underlying organization of the dynamics was not explicitly specified. In particular, it was not made visible that successive positions of objects and organisms necessarily organize themselves into continuous action trajectory shapes in which every actual position directly emerges from the preceding position while simultaneously structurally carrying the further latent development of the trajectory. Nor was it made explicit that the temporal organization of the dynamics manifests itself as the progressive disappearance of a gap toward a point of intersection.

The work of David N. Lee constitutes a decisive next step within this development. Through the introduction of the *tau*-value, Lee was the first to operationalize the temporal structure of externally specified dynamics by demonstrating that time to contact is directly available within the structure of perception itself. This revealed that organisms do not necessarily need to internally calculate future actions but can be directly sensitive to the closing of a gap over time.

The significance of Lee's contribution therefore lies in making explicit the temporal dimension of perception and action. Within his approach, behavior is not guided by static positions, but by the continuous perception of the decreasing distance toward a future point of contact. As a result, the *tau*-value became one of the most influential concepts within ecological theories of perception and found widespread application in movement science, psychology, neuroscience, and robotics.

At the same time, a fundamental structural step remained implicit within Lee's formulation as well. Although Lee correctly identified the phenomenon of gap closure, he did not explicitly specify the necessary conditions under which a closing gap can be perceived in the first place. A closing gap can only exist because an action object develops within a continuous action trajectory shape in which successive positions are necessarily connected and in which the latent development emerges directly from the manifest segment. Gibson and Lee therefore externalized the dynamics of perception, yet neither explicitly demonstrated that the dynamics are necessarily organized in continuous action trajectory shapes that become manifest on the sensory interface across successive moments in time.

Within the GM, this implicit structure is made explicit. The *tau*-value does not appear as an independent variable, but as the direct temporal expression of an underlying externally specified action trajectory shape. The disappearance of a gap therefore does not constitute an isolated phenomenon, but the necessary consequence of the continuous development of an action trajectory shape within which manifest and latent positions remain structurally connected. This makes visible that perception and action are not primarily organized through internal computation, but through continuous attunement to an already externally specified temporal structure as it continuously unfolds on the sensory interface itself.

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1. D. N. Lee – The Tau-Value and Tau-Coupling Theory

With the introduction of the *tau*-value, David N. Lee developed one of the first systematic and experimentally testable models in which the temporal organization of goal-directed action was directly linked to externally available information. Whereas classical approaches generally conceived movement control as an internal process based on computations of distance, velocity, and position, Lee shifted the foundation of action control toward the dynamics of perception itself.

Central to this approach is the concept of the action-gap. An action-gap refers to the difference between an actual state and a future state that must be realized through action. The *tau*-value specifies neither the absolute distance to an object nor the speed at which the object is moving, but rather the time remaining before the relevant gap will be closed, given its current rate of change. Crucially, according to Lee, this information does not need to be internally calculated from separate variables but is directly available within the structure of perception itself.

Within this framework, behavior is organized through continuous attunement to externally unfolding dynamics. Motor actions such as braking, landing, grasping, avoiding, and intercepting can be regulated through direct sensitivity to the closing of gaps, without requiring the organism to explicitly reconstruct distance, velocity, or acceleration. Perception thereby acquires a distinctly prospective character: rather than merely registering the current state of the world, it becomes directly sensitive to the future development of an ongoing interaction. The organism continuously adjusts its actions to a process that is already unfolding externally through time.

An important extension of this approach is Lee's principle of *tau*-coupling. Through *tau*-coupling, multiple simultaneously unfolding gap processes become temporally coordinated, allowing the movement of the organism and the movement of an environmental object to converge toward a future moment of contact. Complex actions are therefore understood not as sequences of separate motor commands, but as continuously coordinated temporal processes within a single perception–action dynamic.

Although Lee originally developed his theory in the context of visual perception and Optic Flow, the underlying principles were subsequently extended to a wide range of perceptual and motor domains. The significance of Lee's contribution lies in demonstrating that the temporal organization of perception and action can be grounded directly in externally available dynamics. Perception is thereby no

longer conceived as the passive registration of static states, but as direct sensitivity to the unfolding course of action through time. It is precisely this externalization of temporal structure that made *tau* theory one of the most influential operationalizations of the ecological approach to perception and action.

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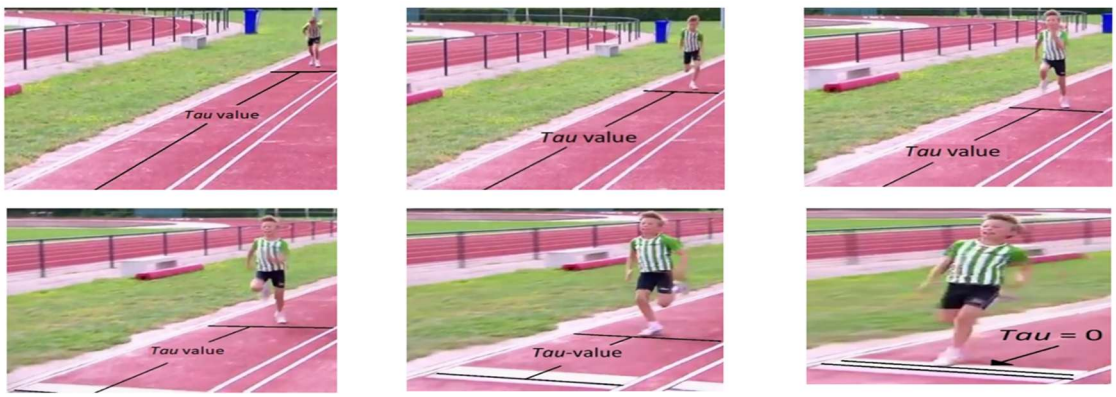
2. The Theoretical Formulation of the Tau-Value by D. N. Lee

Within the work of David N. Lee, the *tau*-value appears as a directly perceivable temporal quantity relating to the closure of a gap. The central idea underlying this formulation is that the information necessary for the control of action does not first need to be internally calculated from separate spatial variables but is directly available within the dynamics of perception itself. The explanation of behavior thereby shifts from internal reconstruction to direct sensitivity to externally available temporal structure.

In his original formulation, Lee defined the *tau*-value as the time-to-closure of a gap. The relevant information does not primarily concern distance or velocity as separate quantities, but rather the temporal relationship through which a gap develops toward complete closure. In his classic 1976 paper, Lee explicitly stated that "the optical information for time-to-collision is directly available in the optic array and does not require the observer to compute distance or velocity" (Lee, 1976, p. 440).

With this formulation, Lee distanced himself from theories that make perception dependent upon internal reconstruction or inference. According to Lee, the information necessary for the regulation of behavior does not need to be derived from elementary sensory data but is already embedded within the structure of the optic array itself. This position was further elaborated in his later work, where he argued that the information required for the control of action is directly available within optic flow. The control of action therefore shifts away from metric reconstruction based on distance and velocity toward direct temporal attunement to externally available dynamics (Lee, 1980, p. 175).

From this perspective, goal-directed actions are understood as processes in which gaps are progressively closed. An action-gap refers to the difference between a current state and a future goal state, while the *tau*-value specifies the temporal structure of the transition between the two. Perception consequently acquires a distinctly prospective character. Rather than reconstructing the current state of the world, the organism becomes directly sensitive to information specifying the future development of an ongoing interaction.



Illustrations: *In his work, D. N. Lee referred to the specific examples of long jump athletes approaching the take-off board, bees approaching a flower, and gannets approaching the surface of the sea, all of which visually bridge a gap. He defined this gap as: "The changing gap between the place you are in now and the place where you want to be." In these examples, it can be observed that the place where you want to be corresponds to the point at which the tau-value becomes zero. According to Lee, this must lead to a coupling between the closing of the gap and the corresponding motor action: a jump or push-off by the long jump athlete as he approaches the take-off board, a landing by the bee as it approaches the flower, and a precisely timed tucking in of the wings by the gannet, enabling it to penetrate deeply into the sea.*

Within this formulation, the relationship between perception and action appears as a process of continuous temporal attunement to externally available dynamics. The current magnitude of the gap corresponds to the present state of the interaction, whereas the progressive closure of the gap coincides with the attainment of the future goal state. Behavior is thereby organized through direct sensitivity to the developing temporal structure of the environment itself.

The significance of Lee's formulation lies in the fact that it represented one of the first explicit attempts to ground the temporal organization of perception and action directly in externally available information. The *tau*-value thereby became more than a descriptive variable; it became a fundamental principle through which goal-directed action could be understood as continuous attunement to an externally unfolding temporal process. In educational contexts, this idea is sometimes summarized by the expression "mind the gap," emphasizing that perception and action are not primarily directed toward objects or positions as such, but toward monitoring and regulating a distance that progressively closes through time. Although this expression does not belong to Lee's original terminology, it captures the central idea that behavior is guided by the direct perception of gap closure.

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3. The Mechanistic Specification of the Tau-Value Within the Gramophone Model

Although David N. Lee identified an extremely important phenomenon within perception and action through the introduction of the *tau*-value, his formulation ultimately remains largely descriptive and insufficiently mechanistically specified. Expressions such as "the place you are in now" and "the place where you want to be" make intuitively clear that actions are organized around the closure of a gap, but they do not specify what this structure actually consists of, how it is organized, nor under which conditions such a gap can become directly perceivable.

Illustrations: *A moving marble in a marble run provides a particularly transparent example of gap closure. Yet such a gap can only arise when both the moving marble and the underlying marble-run structure form one continuous perceptual organization. Without the marble there is no closing gap, but neither can a moving marble generate meaningful temporal organization in the absence of an underlying trajectory structure. The closing gap therefore does not constitute the primary phenomenon. It presupposes a more fundamental organization in which both the moving marble and the marble-run*

structure are integrated into one continuous action trajectory shape. Lee identified the temporal manifestation of this organization through the tau-value, but the underlying organization itself remained largely implicit within his original formulation.

Within Lee's formulation, the *tau*-value appears primarily as a temporal variable relating to the progressive closure of a gap between a current state and a future point of contact. As a result, it remains largely implicit that a closing gap can only exist because an action object develops within a continuous action trajectory shape in which successive positions necessarily emerge from one another and in which the latent course of the movement continuously develops from the manifest segment of the dynamics itself. The perception of a closing gap therefore does not constitute an independent organizing principle of perception and action, but the direct temporal expression of an underlying externally specified action trajectory shape.

This distinction has important consequences. If the closing gap is not the primary phenomenon, then the decisive question is no longer how the organism perceives the gap, but how the underlying action trajectory shape becomes organized within perception. Only once such an organization exists can a gap emerge, develop, and progressively close toward a future point of convergence.

Within the explanatory model of the motoric movement action, this underlying organization is specified explicitly. Perception and action do not appear as processes organized by separate variables, but as continuous attunement to externally specified action trajectory shapes as these are projected onto the sensory surface and unfold across successive time units. The current position P(0) of an action object continuously forms the precise boundary between the manifest segment P(−x) and the latent segment P(+x) of the action trajectory shape, while the latent segment necessarily develops from the manifest segment itself.

Within this framework, the *tau*-value appears as the direct temporal manifestation of the progressive disappearance of the latent segment of the action trajectory shape toward a future point of convergence. The closing of a gap can therefore no longer be understood independently of the continuous trajectory structure within which it develops. Perception, motor action, and cortical mediation consequently appear as components of one continuous externally specified dynamic.

The following sections systematically examine the manifestation of the *tau*-value across different forms of perception and action, including visual, auditory, proprioceptive, and hybrid processes. The aim is to demonstrate that the underlying organization of the *tau*-value remains identical across these domains and continuously emerges from externally specified action trajectory shapes as they are projected onto the sensory surface and unfold across successive time units.

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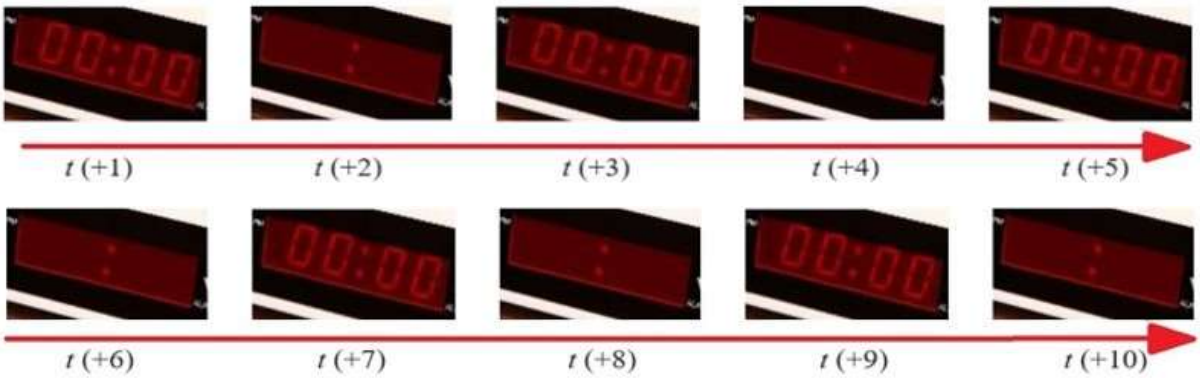
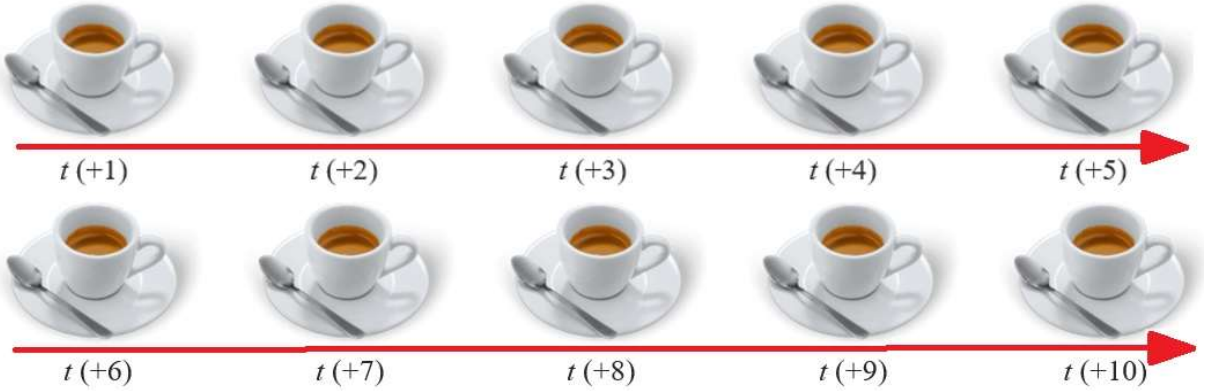
a. Visual Perception – The *Tau*-Value of Stationary Environmental Objects

When grasping a coffee cup, visual perception continuously registers new projections of the cup at successive temporal units that exhibit no positional deviation relative to one another. This continuously active comparison process, which is fundamentally present in all forms of perception, results in the detection of the coffee cup's zero-movement. Although the coffee cup necessarily continues to unfold within the continuous temporal dynamics of reality, its *tau*-value remains constantly zero[19].

[19] https://www.researchgate.net/publication/382069132_Einstein_the_Stationary_Coffee_Cup_and_the_Digital_Clock_The_Visual_Perception_Observes_Stationary_Coffee_Cups_Moving_in_Time?_sg%5B0%5D=ZJlqPe4RqhCz2hW6J5FWHRnu209TW6C8vIT3lnF-beNyVAYafIwPA6bGflWVKZ0T81OOmxJRbnJHgRCmOoLJAH7G4bdhuH2qKCi-lYXOwm.wHkiOHD8YsMzRezrknvz2lgI6wqxB8sg4ekoKaT6i3c2UnLlsM6wu65AKYFgTMQsH1vTeFaW-tcECEMR_ZUJRyg&_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6ImhvbWUiLCJwYWdlIjoicHJvZmlsZSIsInBvc2l0aW9uIjoicGFnZUNvbnRlbnQifX0



The same organizational principle becomes visible in the flashing zeros of a digital clock after a power outage. Each newly appearing projection of the zeros emerges again at exactly the same spatial location. The perception of the first projection possesses no direct physical continuity with later projections apart from their identical positional organization on the sensory surface. It is precisely this continuous comparison of successive projections that makes the perception of zero-movement possible within temporally organized trajectory structures.



We perceive a stationary coffee cup in an identical manner. The contours and boundaries of the cup maintain the same positional organization across successive temporal units, causing the continuous comparison process to stabilize the perception of stillness. Each projection at time point *t(x)* possesses no direct physical identity with projections at later moments *t(x+n)*, yet the continuous positional continuity of the externally specified structure projected onto the sensory surface maintains the perception of zero-movement.

This demonstrates that stillness within visual perception cannot be understood as the absence of dynamics, but rather as a specific form of continuous temporal organization. The *tau*-value remains constantly zero because the externally specified action trajectory shape continues identically across successive temporal units on the sensory surface. Consequently, the perception of stillness emerges not from the absence of change, but from the continuous stabilization of an externally specified structure whose positional organization remains invariant across time.

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b. Visual Perception – The Egocentric Tau-Value

If we wish to get a coffee cup, which performs a zero-movement within a zero-action trajectory shape, into our hands, a point of convergence must be realized between the stationary coffee cup and the egocentric action trajectory shape of the fingertips. The explanatory model of the motoric move-

ment action provides the scientific proof[20] that a perceptual image must first be formed of all future successive fingertip positions that will successfully reach the coffee cup before the action itself can be executed. Only thereafter do the fingertips actually traverse all of these previously latent positions P toward the coffee cup.

As in the case of a marble moving through a marble run, it can be observed that: (1) the current position of the fingertips P(0) always forms the precise boundary between the manifest positions P(−x) and the latent positions P(+x) of the action object within the action trajectory shape, (2) the latent segment must necessarily emerge from the manifest segment, and (3) the gap within the latent segment progressively closes toward zero.

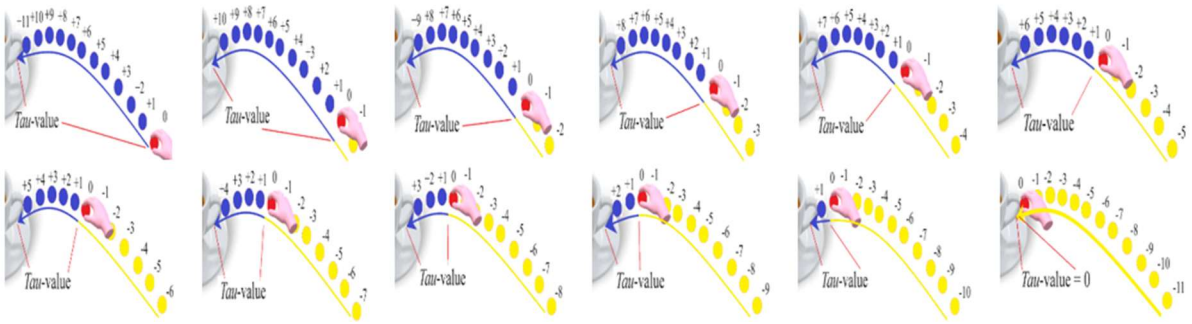


Illustration: *The tau-value can be perceived in two autonomous ways. 1. The manifest (yellow) positions of the action object progressively fill the latent (blue) action trajectory shape, whereby the already realized segment gradually takes over the not-yet-realized perceptual image. 2. The same process can be perceived solely as the progressive disappearance of the latent (blue) segment itself as the remaining gap approaches zero. This latter mode constitutes the most elementary form of tau-perception.*

Within this process, the *tau*-value, as projected onto the sensory surface, can be perceived in two autonomous ways, which in practice will often occur in hybrid combinations. On the one hand, the *tau*-value may be perceived as the process by which the manifest positions of the fingertips progressively fill the perceptual image of the latent trajectory. In which the already realized segment of the action trajectory shape gradually takes over the not-yet-realized perceptual image.

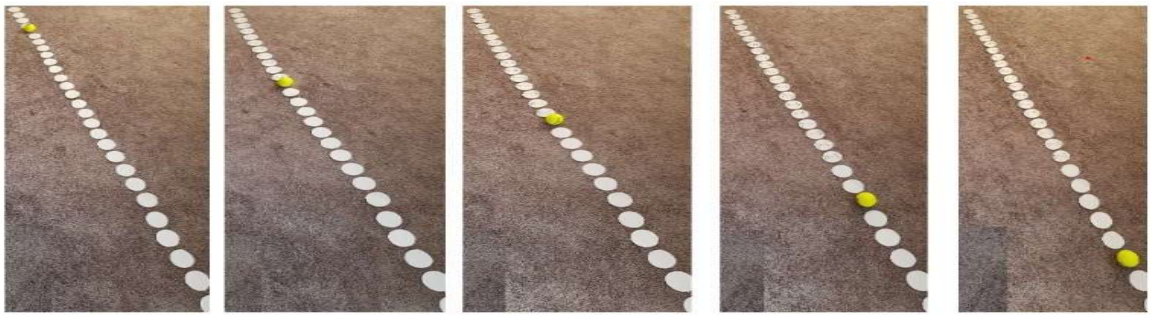
On the other hand, the same process may be perceived as the progressive disappearance of the latent positions themselves, whereby only the remaining distance to the future point of convergence is observed to diminish toward zero—the closing of the gap. This second mode constitutes the most elementary perception of the *tau*-value. It requires nothing more than the detection of the progressive disappearance of the latent segment itself.

---

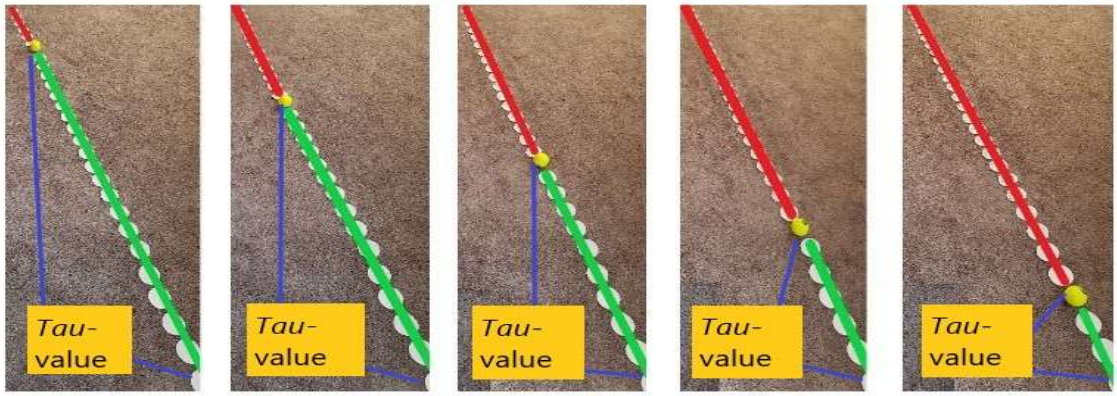
c. Visual Perception – The Tau-Value of Moving Environmental Objects

In the case of a moving environmental object, such as a tennis ball, all successive positions P are likewise necessarily connected. The latent segment of the approaching ball trajectory shape must therefore necessarily develop from the manifest segment of the action trajectory shape. On the basis of universal and specific cognitive movement knowledge, professional tennis players can, after observing only a limited number of manifest projections of the tennis ball as projected onto the retina, already form a global perceptual image of the further development of the approaching ball trajectory shape.

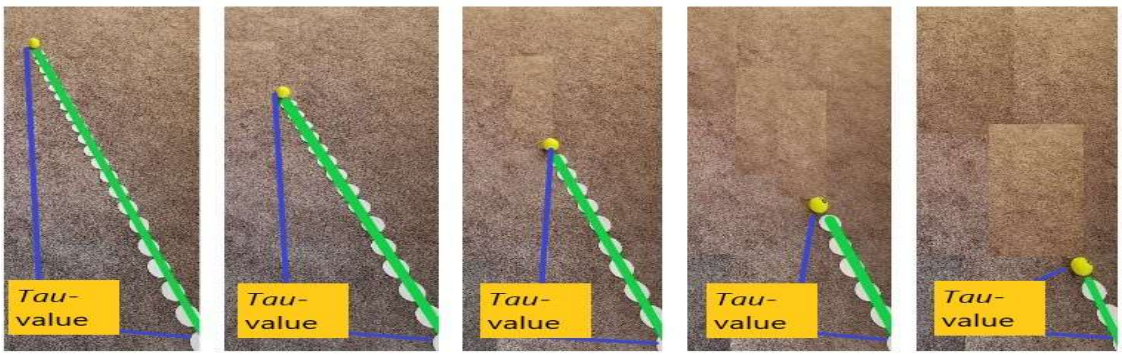
[20] https://www.researchgate.net/publication/380792810_GRASPING_Within_the_grasping_of_a_coffee_cup_we_always_first_construct_a_perceptual_image_of_a_latent_action_trajectory_shape_out_of_the_perspective_of_the_fingertips_-_The_scientific_evidence



Here too, the tennis ball subsequently traverses all of these previously latent positions P. As in the case of a marble moving through a marble run, it can be observed that: (1) the current position of the tennis ball P(0) always forms the precise boundary between the manifest segment P(−x) and the latent segment P(+x) of the action trajectory shape, (2) the latent segment must necessarily emerge from the manifest segment, and (3) the gap within the latent segment progressively closes toward zero.

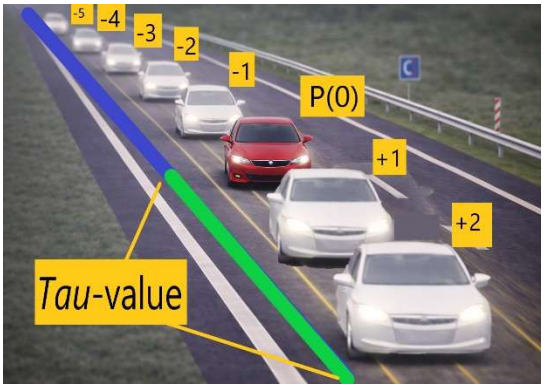


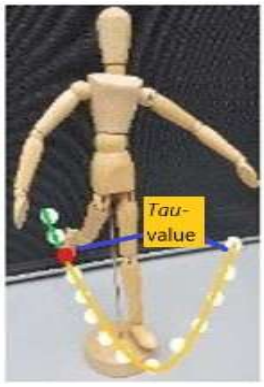
Within this process, the *tau*-value, as projected onto the sensory surface, can likewise be perceived in two different ways, which in practice will often occur in hybrid combinations. The first mode consists of perceiving the *tau*-value as the process by which the manifest positions of the tennis ball progressively fill the latent trajectory, whereby the already realized segment of the action trajectory shape gradually takes over the not-yet-realized perceptual image. The second mode consists of perceiving the same process as the progressive disappearance of the latent positions themselves, whereby only the remaining distance in time is observed to be progressively reduced toward zero. This latter mode constitutes the most elementary form of *tau*-perception and represents the perception of gap closure in its purest form.

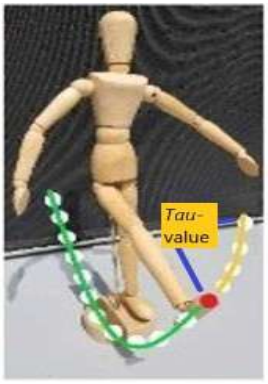


It is ultimately irrelevant which action object is moving. Perceptual processes continuously assume that all positions of any action object are structurally connected within one continuous action trajectory shape and that a corresponding *tau*-value thereby necessarily emerges. Depending on the

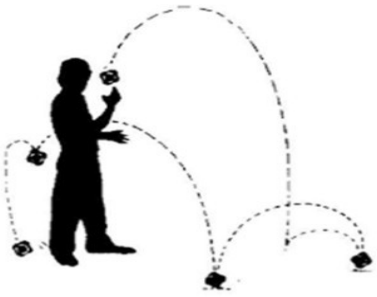
regularity of the action trajectory shape, cognitive movement knowledge subsequently enables more or less reliable judgments to be made about the further development of this *tau*-value.



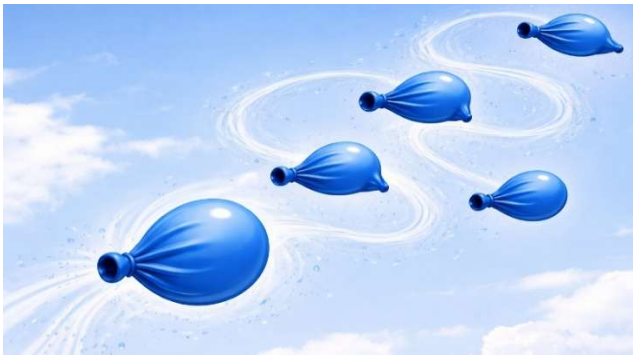




Within traffic situations, the future development of *tau*-values can often be estimated relatively reliably because vehicles typically move within clearly defined lanes and are constrained by relatively predictable velocities. Likewise, in combat situations, approaching body parts can often be perceived at an early stage as continuous action trajectory shapes whose global development can be followed with a reasonable degree of reliability.



Z-ball bounce behaviour



This is different in the case of, for example, a bouncing Z-ball or a deflating balloon. Although all manifest positions here likewise remain necessarily connected within one continuous action trajectory shape, human perception is largely unable to make reliable judgments about how the latent segment of the action trajectory shape will develop from the manifest segment. Consequently, it becomes extremely difficult to form a stable perceptual image of the future development of the action trajectory shape and thereby to perceive a reliable *tau*-value. These examples demonstrate that the perception of a *tau*-value depends directly on the extent to which the latent segment of an action trajectory shape can be specified from its manifest part. Whereas relatively regular action trajectory shapes allow the future development of the latent segment to be perceived with a reasonable degree of reliability, highly irregular action trajectory shapes severely constrain this possibility and thereby undermine the reliable perception of a corresponding *tau*-value.

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d. Visual Perception – The Tau-Value of an Egocentric Movement Toward a Moving Environmental Object

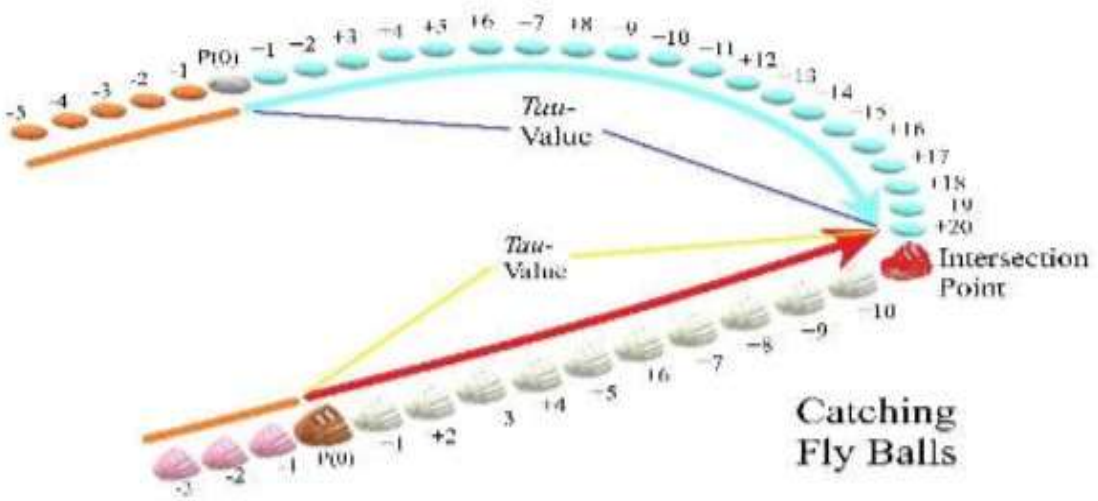
If we now wish to catch an approaching tennis ball[21], then—just as in the case of grasping a coffee cup—we must first develop an egocentric action trajectory shape, because the fingertips must

[21] https://www.researchgate.net/publication/383915944_A_Clarification_of_the_Relation_Between_Affordances_and_the_Continuous_Visual_Guidance_of_Action_When_Catching_Fly_Balls_The_Autonomous_Movement_of_the_Glove_and_Ball_Affords_Perceptual_Images_of_Two

again be moved in a specific manner toward a future point of convergence. The difference, however, is that a point of convergence must now be selected between the approaching ball trajectory shape and the egocentric action trajectory shape of the catching hand. This means that, on the basis of the first manifest positions of both the tennis ball and the catching hand, as projected onto the visual sensory surface, a perceptual image must emerge of two latent action trajectory shapes that must jointly lead to a future point of convergence.

In this situation, more complex than in the previous examples, two autonomous action trajectory shapes associated with two moving objects must simultaneously be perceived, analogous to two marbles moving through two separate marble runs. As a consequence, two autonomous *tau*-values emerge within perception, whereby the *tau*-value of the approaching ball trajectory shape organizes the development of the corresponding *tau*-value of the egocentric action trajectory shape of the catching hand[22].

Here too, it can be observed that: (1) the current position P(0) of both the tennis ball and the catching hand continuously forms the precise boundary between the manifest segment P(−x) and the latent segment P(+x) of their respective action trajectory shapes, (2) the latent segment of both action trajectory shapes must necessarily emerge from the manifest segment, and (3) the gaps within both latent trajectories progressively close toward their shared point of convergence.

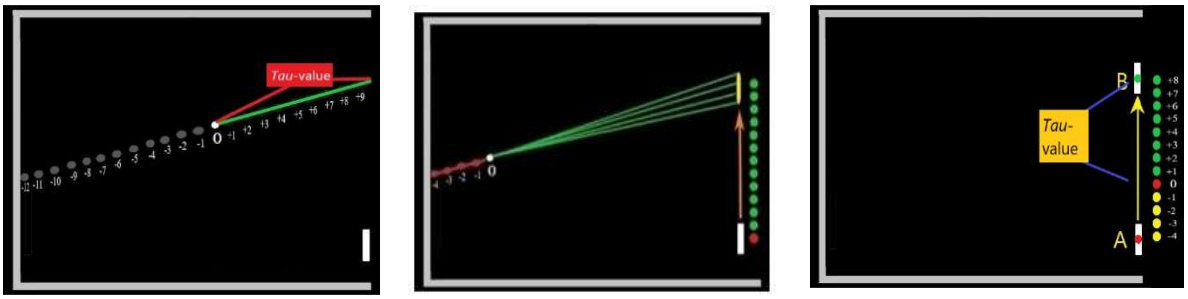


Within this process, the *tau*-value can again be perceived in two different ways, which in practice will often occur in hybrid combinations. The first mode consists of perceiving the *tau*-value as the process by which both the manifest positions of the tennis ball and those of the catching hand progressively fill their respective latent trajectories. The second mode consists of perceiving the same process as the progressive disappearance of the remaining distance between both action trajectory shapes toward their shared point of convergence—the closing of the gap. This latter mode constitutes the simplest and most elementary form of *tau*-perception, representing the perception of gap closure in its purest form.

Within the game of Pong[23], this process unfolds identically to the catching of a ball. Through its manifest projections on the retina, the pong ball establishes a direct feedback coupling with the brain, mak-

[22] https://www.researchgate.net/publication/383915944_A_Clarification_of_the_Relation_Between_Affordances_and_the_Continuous_Visual_Guidance_of_Action_When_Catching_Fly_Balls_The_Autonomous_Movement_of_the_Glove_and_Ball_Affords_Perceptual_Images_of_Two_
[23] https://www.researchgate.net/publication/395396068_The_Cortical_Streams_Simultaneously_Mediate_Two_Autonomous_Phenomena_within_Pong_The_Independent_Predictive_Coding_Predictive_Processing_and_Prediction_Errors_of_the_Pong_Ball_and_the_Paddle?_sg%5B0%5D=MWL

ing it possible to form a perceptual image of the global future development of the ball trajectory shape. The pong ball thereby moves as one overarching action phenomenon, analogous to a marble moving through a marble run, and must therefore likewise be understood as one continuous action trajectory shape.



The closing of the gap between the pong ball and a future point of convergence with the action trajectory shape of the paddle can, in its most elementary form, be perceived as the progressive disappearance of a line segment. The action trajectory shape of the paddle is organized in relation to the approaching ball trajectory shape, which necessarily serves as the leading action trajectory shape because its future development is externally specified and cannot be directly controlled by the organism. From the current position of the paddle, as projected onto the retina, the brain fills in the intermediate positions within a direct feedback loop toward the future point of convergence of both action trajectory shapes.

The paddle, whose movement can be directly controlled by the organism, subsequently also generates manifest projections on the retina, causing the disappearance of the gap of the pong ball to become progressively synchronized with the disappearance of the gap of the paddle toward the shared point of convergence of both action trajectory shapes. As a result, the development of the egocentric action trajectory shape becomes continuously attuned to the externally specified development of the ball trajectory shape.

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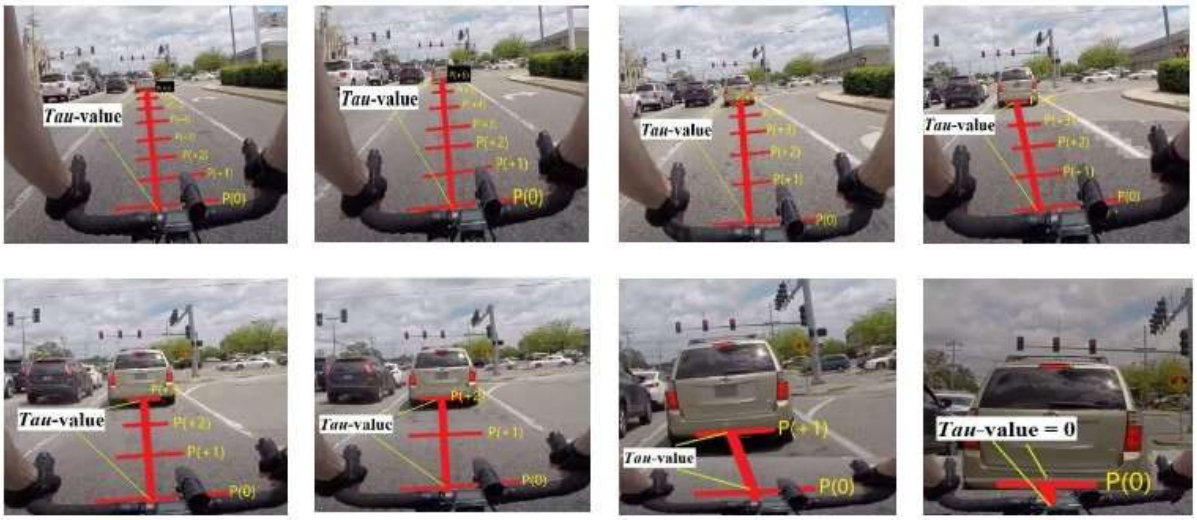
e. Visual Perception – The Organization of Multiple Tau-Values

Within everyday actions *tau*-values rarely manifest in isolation. Instead, they emerge as components of complex and simultaneously unfolding action dynamics. This becomes particularly evident in traffic situations, where multiple autonomous action trajectory shapes develop concurrently and must continuously be perceived and regulated in relation to one another. Although the *tau*-value of an approaching vehicle has already been discussed separately, actual traffic situations give rise to numerous additional *tau*-values that together constitute one integrated perceptual dynamic.

The *tau*-value of an egocentric cycling movement can, for example, be represented as a continuous action trajectory shape in which the current position of the cyclist P(0) continuously forms the precise boundary between the manifest segment P(−x) and the latent segment P(+x) of the egocentric movement trajectory. Within traffic situations, however, these egocentric *tau*-values must generally avoid converging with the action trajectory shapes of other road users[24]. Traffic perception therefore develops into an extremely complex organization of simultaneously unfolding *tau*-values that must continuously be regulated and coordinated in relation to one another.

[24] In bumper cars, the opposite principle applies: the action is often organized around intentionally realizing points of convergence with the action trajectory shapes of other participants.



Here too, the structural principles remain identical: (1) all manifest positions of both the cyclist and the other road users necessarily remain connected within continuous action trajectory shapes, (2) the latent segment of each action trajectory shape must necessarily emerge from its manifest segment, and (3) the different *tau*-values continuously develop in relation to potential future points of convergence that must be avoided, regulated, or continuously monitored.

This demonstrates that complex traffic perception does not depend upon separate internal calculations of isolated objects, but upon the continuous perceptual attunement to multiple autonomous action trajectory shapes that simultaneously realize themselves on the sensory surface. Within this complex dynamic, visual *tau*-values do not emerge independently, but as components of one integrated perceptual field in which all relevant action trajectory shapes are continuously organized in relation to one another.

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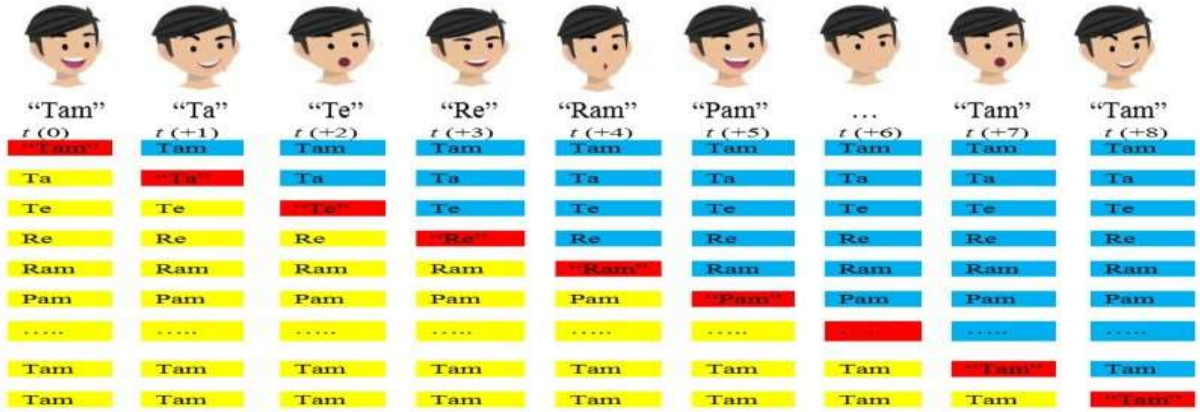
f. Auditory Perception – Tau-Values in Language[25]

In contrast to James J. Gibson and David N. Lee, whose analyses primarily focused on visual perception and optic-flow-related dynamics, the GM demonstrates that the externally specified structure, as projected onto the sensory surface, is present in an identical manner across all forms of perception, including auditory perception[26].

[25] https://www.researchgate.net/publication/361184701_The_cortical_streams_mediate_the_auditory_perception_of_soundswords_in_the_exact_same_way_as_they_mediate_the_visual_perception_of_an_incoming_ball_trajectory_shape_-_The_zig-zag-process_and_the_harmo

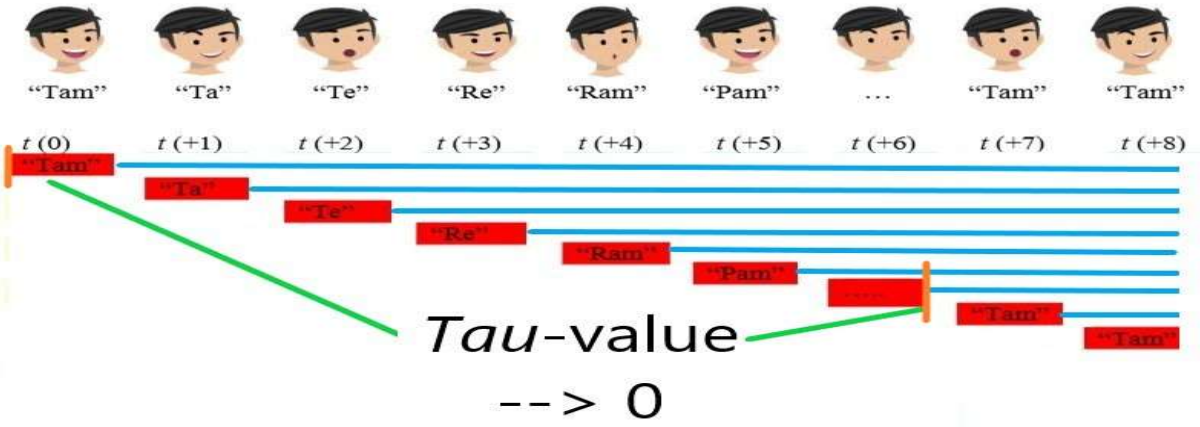
[26] The explanatory model of the motoric movement action, as developed within the GM, is likewise capable of providing a mechanistic explanation of speech, self-talk, inner language, and related auditory phenomena. However, because the theoretical foundations required for such an explanation remain largely absent from the current scientific discourse, a detailed treatment would be unlikely to be properly understood at present and is therefore omitted here.

When speaking, words are coupled together in a specific temporal sequence, strictly regulated by the intervening pauses and temporal transitions. During listening, these words and pauses are necessarily received in exactly the same order. Here too, in accordance with the visual perception of action trajectory shapes, it can be observed that: (1) one continuous auditory action trajectory shape is formed, (2) the latent segment necessarily develops from the manifest segment, and (3) the currently spoken word continuously forms the precise boundary between the manifest and latent segments of the action trajectory shape.



Auditory perception therefore likewise gives rise to a continuous marble–marble-run relation. The currently spoken word develops within a perceptual image of the complete sentence structure toward the future endpoint of the sentence. This becomes particularly apparent when attention is directed not toward ordinary conversation, but toward a familiar chant or yell.

After hearing only two or three words of such a chant, a listener will typically already have formed a global perceptual image of the complete latent action trajectory shape. This makes it possible to auditorily anticipate the remaining words of the chant in accordance with its current tempo and, in many cases, to complete the final words before they have actually been spoken.



Here too, the *tau*-value appears, as projected onto the sensory surface, as the direct temporal manifestation of the progressive disappearance of the latent segment of the auditory action trajectory shape toward the future endpoint of the sentence. As successive words become manifest, the latent segment of the sentence structure progressively decreases until the entire auditory action trajectory shape has unfolded and reached its future endpoint.

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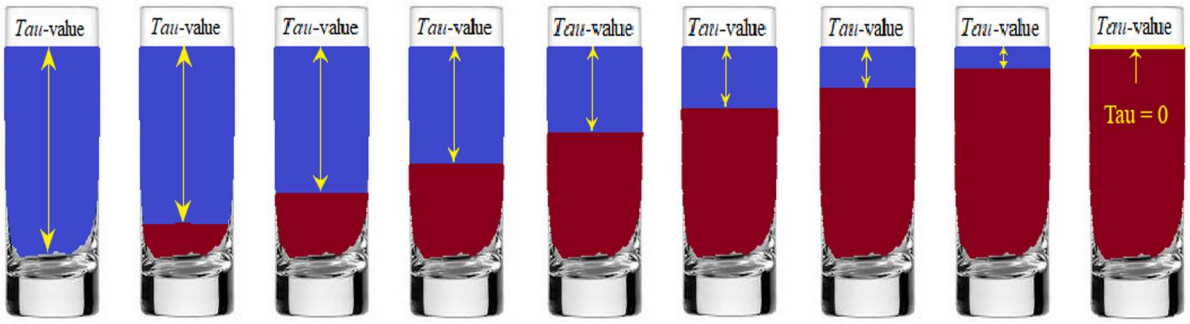
g. Auditory Perception – Tau-Values in Filling Objects

The filling of objects[27] such as glasses, buckets, watering cans, and similar containers will generally be guided primarily by visual perception, since vision typically functions far more accurately than auditory perception during such actions. Nevertheless, a clear auditory *tau*-value can also be perceived during the filling process. As the liquid level rises, the pitch and resonance of the sound progressively change, making it possible to perceive with increasing precision when the future overflow point is approaching. This enables the filling process to be terminated at exactly the right moment, immediately before the container overflows. Consequently, even in complete darkness, objects can often be filled with a relatively high degree of accuracy on the basis of auditory information alone.

Although auditory *tau*-values are generally less precise than visual *tau*-values, the underlying structural principles remain identical. Here too, perception depends upon the continuous comparison of successive auditory projections, whereby the latent segment progressively develops from the manifest segment and the temporal organization of the auditory action trajectory shape unfolds toward a future endpoint.



The manner in which an auditory *tau*-value is phenomenologically experienced is difficult to reconstruct precisely in written form, yet its underlying organization corresponds closely to the visual perception of *tau*-values. During the filling of a bucket, watering can, glass, or similar container, the remaining empty segment progressively decreases as the liquid level rises. As a consequence, the auditory projections generated by this remaining empty segment systematically change, producing gradual shifts in pitch, resonance, and overall sound quality. These auditory changes are not experienced as isolated sensory events, but as a continuous temporal development that progressively approaches a future endpoint. As the remaining empty segment becomes smaller, the corresponding auditory *tau*-value likewise approaches zero, enabling increasingly precise perception of the approaching overflow point. The listener thereby becomes directly sensitive to the progressive disappearance of the remain-

[27] https://www.researchgate.net/publication/382297474_The_complete_clarification_of_all_functional_perception_processes_within_pouring_and_filling?_sg%5B0%5D=ZJlqPe4RqhCz2hW6J5FWHRnu209TW6C8vIT3lnF-beNyVAYafIwPA6bGflWVKZ0T81OOmxJRbnJHgRCmOoLJAH7G4bdhuH2qKCi-lYXOwm.wHkiOHD8YsMzRezrknvz2lgI6wqxB8sg4ekoKaT6i3c2UnLlsM6wu65AKYFgTMQsH1vTeFaW-tcECEMR_ZUJRyg&_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6ImhvbWUiLCJwYWdlIjoicHJvZmlsZSIsInBvc2l0aW9uIjoicGFnZUNvbnRlbnQifX0

ing empty segment, allowing the filling process to be terminated at the appropriate moment before the container reaches its maximum capacity.

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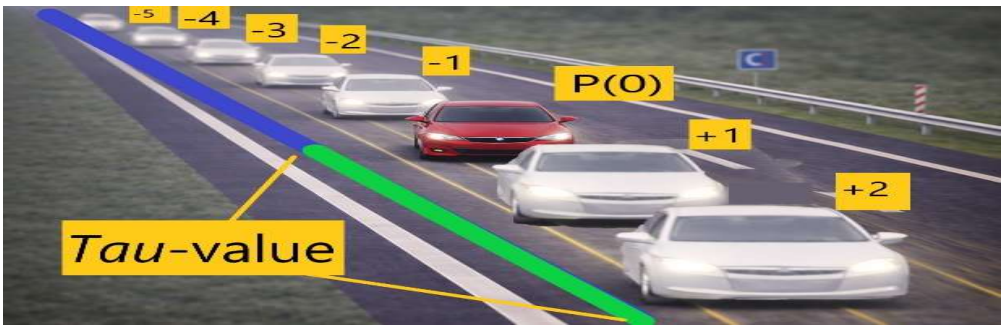
h. Auditory Perception – Tau-Values in Traffic Situations

The auditory perception involved in filling objects, as explained in the previous paragraph, is based upon a temporal organization that closely resembles the Doppler effect experienced in everyday encounters with moving vehicles, as previously discussed in relation to the visual perception of an approaching car[28].

The Doppler effect is an auditory phenomenon in which the perceived frequency of a sound changes as a consequence of relative movement between a sound source and an observer. As an object approaches, its frequency is perceived as progressively increasing; as the object moves away, the perceived frequency progressively decreases.



Within the framework of the *tau*-value, however, these frequency changes cannot be understood merely as isolated physical properties. Rather, they constitute the direct auditory manifestation of a continuously developing action-gap. The increasing pitch of an approaching object corresponds to the progressive closure of the gap through time, whereas the decreasing pitch following passage corresponds to the progressive reopening of the gap as the object moves away.

Consequently, as in visual perception, what is perceived on the sensory surface is not primarily a static quantity but a continuously unfolding temporal process. Information concerning the approach or withdrawal of an object is not derived from separate variables such as distance or velocity, but is directly available within the structured transformation of the auditory projection itself, as it develops on the sensory surface. In this sense, the Doppler effect functions as an auditory specification of the *tau*-value, making the temporal organization of external dynamics directly audible.

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[28] Throughout this article, an attempt is made to isolate individual phenomena as much as possible in order to clarify their underlying organization. At the same time, the GM consistently emphasizes that genuinely unimodal perception does not occur in practice and that perception is fundamentally transmodal in nature. Particular sensory modalities may become dominant within specific situations, but they never operate in complete isolation. In traffic situations, for example, *tau*-values are primarily perceived through a combination of visual and auditory information, with auditory perception often providing the initial indication that an object is approaching before detailed visual regulation takes over.

i. Proprioceptive Perception - The Tau-Value of Opening a Lock in Complete Darkness

Tau-values can also be perceived entirely through proprioception. When, for example, we attempt to open a lock in complete darkness[29], we first bring the non-key hand to the lock. Through the localization and fixation of the lock, a perceptual image of a latent action trajectory shape between the key and the lock can subsequently be formed as part of the proprioceptive perceptual process. From this reference point, the key can then be guided toward the lock solely on the basis of proprioceptive and haptic perception, following the perceptual image of the action trajectory shape. The key can thereby be moved entirely through proprioceptive perception along the action trajectory shape, while the organism directly senses when the *tau*-value within this trajectory shape approaches zero.

Here too, the structural principles remain identical: (1) the current position P(0) of the key continuously forms the precise boundary between the manifest segment P(−x) and the latent segment P(+x) of the action trajectory shape, (2) the latent segment must necessarily emerge from the manifest segment, and (3) the gap within the latent segment progressively closes toward zero as the key approaches the lock. As in the previous examples, the future development of the action trajectory shape is not perceived as a collection of isolated positions, but as one continuous trajectory extending from the current position of the key toward the future point of convergence with the lock.

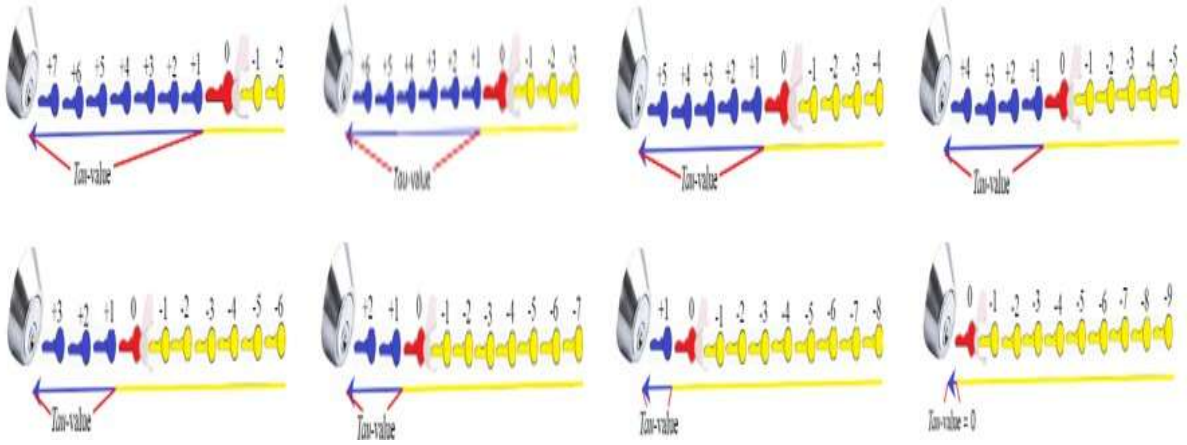
Within this process, the *tau*-value can be perceived in the same two autonomous ways described previously, which in practice will often occur in hybrid combinations. The first mode consists of perceiving how the manifest positions of the key progressively fill the latent trajectory shape, whereby the already realized segment gradually takes over the not-yet-realized perceptual image. The second mode consists of perceiving the progressive disappearance of the remaining gap itself, whereby it can be directly felt how the gap is reduced through time until the *tau*-value approaches zero and the correct key–lock configuration is achieved. This latter mode constitutes the most elementary form of proprioceptive *tau*-perception, because it requires only direct sensitivity to the progressive disappearance of the remaining gap.

j. Proprioceptive Perception – The Tau-Value of Opening a Lock in Daylight

When the same action is performed in daylight[30], it may appear as if the movement is guided exclusively by vision. This is not the case. Although visual perception is now the dominant modality,

[29] https://www.researchgate.net/publication/342736953_The_complete_functional_explanation_of_all_proprioceptive_perception_processes_-_The_behavioural_perception_processes_within_the_opening_of_a_door_lock_within_pitch_black_darkness?_sg%5B0%5D=qa5phczs
[30] https://www.researchgate.net/publication/382267910_The_complete_clarification_of_all_functional_perception_processes_when_opening_a_lock_with_a_key?_sg%5B0%5D=ZJlqPe4RqhCz2hW6J5FWHRnu209TW6C8vIT3lnF-beNyVAYafIwPA6bGflWVKZ0T81OOmxJRbnJHgRCmOoLJAH7G4bdhuH2qKCi-lYXOwm.wHkiOHD8YsMzRezrknvz2lgI6wqxB8sg4ekoKaT6i3c2UnLlsM6wu65AKYFgTMQsH1vTeFaW-tcECEMR_ZUJRyg&_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6ImhvbWUiLCJwYWdlIjoicHJvZmlsZSIsInBvc2l0aW9uIjoicGFnZUNvbnRlbnQifX0

autonomous proprioceptive perception remains continuously active throughout the entire action, just as it does when the same motor action is executed in complete darkness. The key therefore continues to be guided not only by visual information, but also by proprioceptive and haptic information concerning the position and movement of the hand, the key, and their relation to the lock. Consequently, the *tau*-value of the action trajectory shape can still be perceived proprioceptively as it progressively approaches zero.



Illustrations: *The closing of the gap, within lock opening with a key, can be perceived in two autonomous ways. The first consists of observing how the manifest (yellow) segment progressively fills the perceptual image of the latent (blue) action trajectory shape. The second consists of perceiving only the progressive disappearance of the latent (blue) segment itself, whereby the remaining gap is observed to diminish toward zero. This latter mode constitutes the most elementary form of tau-perception because it requires only sensitivity to the progressive disappearance of the remaining latent segment.*

This dual perceptual organization allows the action to develop smoothly and continuously. When visual information becomes temporarily unavailable or less reliable, proprioceptive and haptic perception continue to support the ongoing regulation of the action. In this sense, perception is not organized through separate sensory systems operating independently, but through an intrinsically hybrid or transmodal organization in which the same underlying action trajectory shape is simultaneously specified across multiple sensory modalities and projected onto their respective sensory surfaces.

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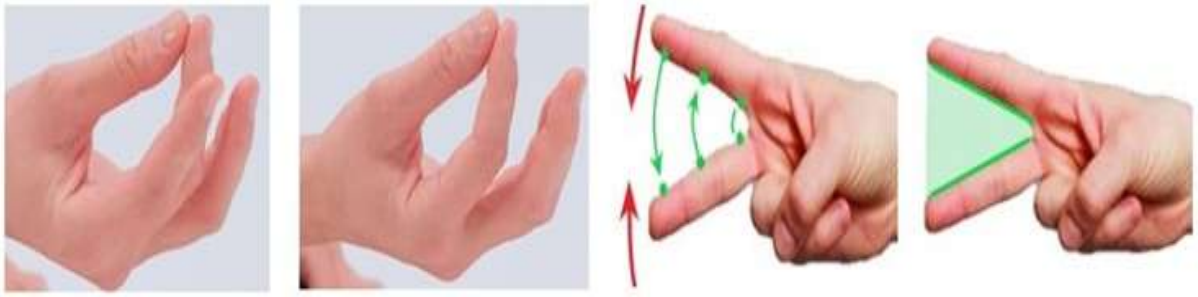
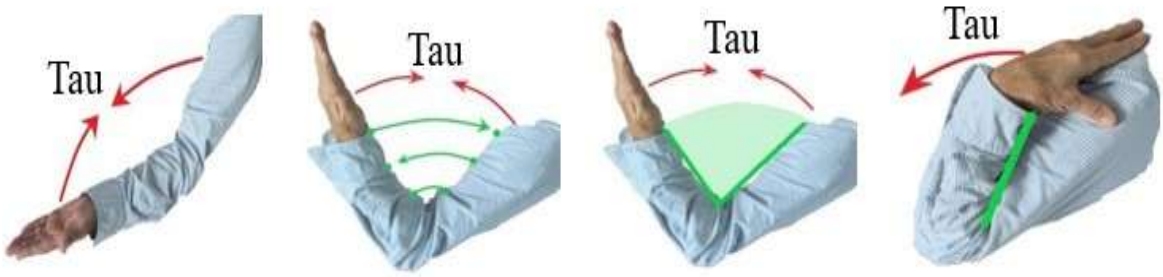
k. Proprioceptive Perception – Complex Proprioceptive Tau-Configurations

The proprioceptive perception of *tau*-values has thus far been described in a largely isolated manner in order to clarify its underlying organization. In actual behavior, however, highly complex configurations of simultaneously developing *tau*-values arise almost immediately. When, for example, a relatively simple action trajectory shape is realized between the fingertips and a coffee cup, one dominant external *tau*-value emerges between the fingertips and the cup. At the same time, all participating body segments continuously move in relation to one another.

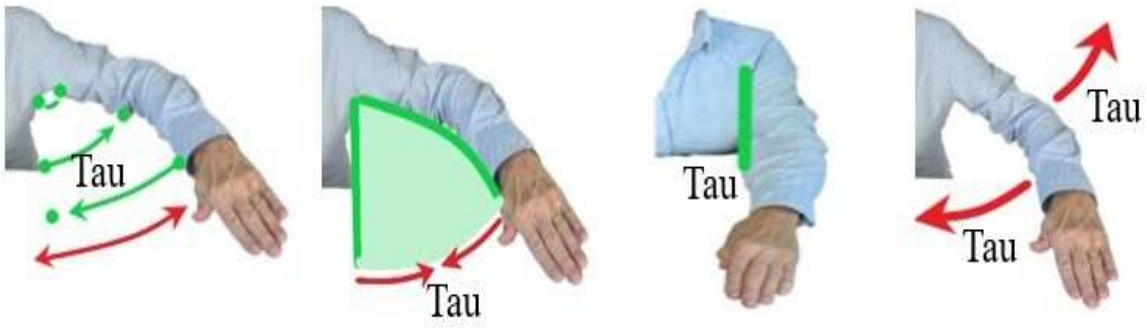
Consequently, even within this seemingly simple action, numerous additional proprioceptive *tau*-values arise between the fingers, hand segments, wrist, forearm, upper arm, shoulder, and trunk. Each relational configuration between these body segments may itself constitute an autonomous action trajectory shape possessing its own manifest and latent structure, its own gap dynamics, and its own *tau*-value.



This complexity becomes particularly apparent within hand–finger relations. Not only can individual fingertips move toward one another in a variety of ways, but finger subsegments, hand surfaces, and entire geometric configurations may likewise become organized as autonomous action trajectory shapes under attentional focus. For each of these action trajectory shapes, perceptual sensitivity exists regarding their spatial organization, their developing *tau*-values, and the manner in which they are cortically mediated.

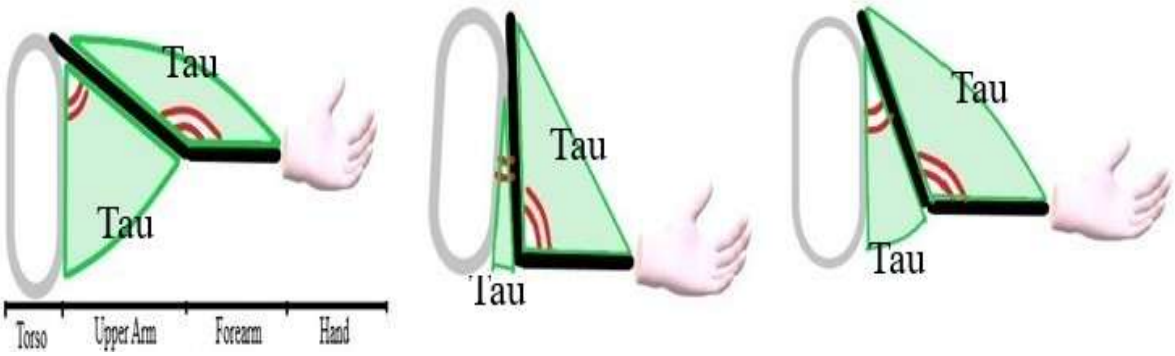


The same principle applies to the relations between forearm and upper arm, arm and trunk, or between both arms. Here too, body segments can organize themselves into numerous relational configurations. Within each configuration, a perceptual image emerges of a latent action trajectory shape within which the manifest positions of the relevant body segments progressively develop toward a future point of convergence.



The essence of this proprioceptive organization does not lie in isolated muscle contractions or individual motor commands, but in the continuous perceptual organization of relational action trajectory shapes under attentional focus[31]. Only when attentional focus becomes directed toward particular body segments does a perceptual image emerge of the relevant latent action trajectory shapes. This makes it possible to directly perceive how body segments develop in relation to one another, when maximal amplitudes are approached, and how gaps progressively move toward closure.

[31] The explanation of the Rubber Hand Illusion reveals this selective attentional process: https://www.researchgate.net/publication/397770908_The_Complete_Mechanistic_Clarification_of_The_Rubber_Hand_Illusion_-_Why_External_and_Internal_Hand_Perception_Are_Autonomous_and_Cannot_Be_Unified_Without_Motor_Action



It therefore becomes apparent that even the simplest actions depend upon an extraordinarily complex organization of simultaneously developing proprioceptive *tau*-values. The body does not function as a collection of isolated segments, but as one integrated relational field of autonomous action trajectory shapes that are continuously organized, coordinated, and cortically mediated in relation to one another.

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4. Conclusion

With the introduction of the *tau*-value, David N. Lee made explicit one of the most fundamental phenomena within perception and action: the direct perception of gap closure through time. In doing so, he demonstrated that organisms do not necessarily need to internally calculate future actions on the basis of distance, velocity, or position, but can instead be directly sensitive to the temporal organization of externally available dynamics. Lee thereby operationalized a crucial dimension of James J. Gibson's ecological approach and made it experimentally accessible across a wide range of domains involving perception, movement, and action control.

At the same time, Lee's formulation leaves largely implicit the structural conditions under which a closing gap can become directly perceivable in the first place. A gap can only exist because successive positions of environmental objects and egocentric movements become organized within continuous action trajectory shapes in which each current position necessarily emerges from preceding positions while simultaneously constraining the further latent development of the trajectory. The perception of a closing gap therefore does not constitute an independent organizing principle, but rather the direct temporal manifestation of an underlying externally specified action trajectory shape.

Within the Gramophone Model (GM), it is precisely this implicit structure that becomes explicitly specified. Perception, motor action, and cortical mediation do not appear as separate internally organized processes, but as the continuous attunement to externally specified action trajectory shapes that realize themselves on their respective sensory surfaces from moment to moment. The current position P(0) continuously forms the precise boundary between the manifest segment P(−x) and the latent segment P(+x) of the action trajectory shape, while the latent development must necessarily emerge from the manifest segment. Within this dynamic, the *tau*-value appears as the direct temporal manifestation of the progressive disappearance of the latent segment toward a future point of convergence.

It thereby becomes apparent that the structural organization of the *tau*-value is not restricted to visual perception, but manifests itself identically within auditory, proprioceptive, haptic, and hybrid perceptual processes. Likewise, the same *tau*-structure can be perceived simultaneously from multiple autonomous perspectives, because it does not originate from a single subjective reference point, but from the structural organization of the external dynamics itself.

The fundamental significance of Lee therefore lies in the identification and operationalization of an essential temporal phenomenon within perception and action. The GM builds upon this achievement by explicitly specifying the underlying structural organization of that dynamic. The explanatory focus

thereby shifts definitively away from internal calculation and toward the continuous attunement to externally specified action trajectory shapes as they directly realize themselves on their respective sensory surfaces.

The examples discussed throughout this chapter further demonstrate that the perception of a *tau*-value depends directly upon the extent to which the latent segment of an action trajectory shape can be specified from its manifest segment. A *tau*-value does not emerge independently, but only insofar as the future development of the latent segment remains structurally constrained by the manifest segment from which it develops. Relatively regular action trajectory shapes therefore permit reliable perception of *tau*-values, whereas highly irregular action trajectory shapes constrain the specification of the latent segment and thereby undermine the reliable perception of a corresponding *tau*-value. In all cases, the role of cortical mediation is not to generate the action trajectory shape itself, but to stabilize the organism's continuous interaction with an externally specified dynamic as projected onto the respective sensory surface.

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